THE FUNDAMENTALS OF NAVAL TACTICS

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OF

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BY

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FOREWORD.

This work is a systematic codification in treatise form of the mathematical principles of Naval Tactics. The author is the instructor in the Art of Naval War at the Royal Italian Naval Academy, and his name is well known as the writer of a number of excellent articles of much original thought on naval tactics in the Revista Marittima.

He is therefore well fitted for the task of reducing to the consecutive order and logical sequence, so necessary to the student, tactical principles and theorems. Tactics is an ever changing art; for while its scientific *principles* do not change, its *rules* necessarily change with changing conditions.

No books on tactics will ever solve the problem finally, because the problem is forever changing; but if its *methods* are correct, these will ever be of value.

Even if we do not agree with all the views of the author and of the other of his distinguished compatriots whose views he has here embodied, the work would be of value as expressing the Italian point of view; and Italy stands in the first rank of naval thought.

As the title indicates, the book deals chiefly with the fundamentals, and approaches the subject more particularly from the mathematical side.

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INTRODUCTION.

The study of naval tactics has for its object the employment of ships in battle. This does not mean that the field of such inquiry is limited simply to that in which the weapons are in action (offensive contact); indeed it is well understood that, directly in relation to the battle, the movements of the two adversaries from the time of their sighting each other are to be considered; furthermore, on the information obtained from the units that keep the enemy in sight, the remainder of the forces can be arranged in the most opportune way for its tactical employment. Therefore, under the head of *tactical contact,* besides the above-mentioned form (offensive contact), it is well to include also that of *contact out of range.*

To proceed from the simple to the complex, let us examine successively:

I. *The elements of maneuvering;* seeking to establish the importance of the various elements (angles and distances) by means of the examination of the *momentary tactical situations;* considering the mobility of the adversaries only in so far as it affects the probability of hitting with the weapons.

II. *Maneuvering;* examining how, by its effect, the tactical situation may be subjected to change.

III. *Tactical action as a whole,* on the basis of the above-mentioned parts, completing the picture of the battle which results from them.

One may find a certain reluctance in admitting the convenience of studying the momentary situation apart from the maneuvering, but it is necessary to consider that if the study of the movement is put first, it would appear to be necessary to leave the other out.

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PART I.

THE ELEMENTS OF MANEUVERING.

CHAPTER I.

DIRECTIONS OF MAXIMUM UTILIZATION.

1. *Definitions.*—We call *long-range combat* that which is developed within the limits of distance which permit the use of guns only.

By the *polar bearing* of a point is meant the angle that the line joining the center of the ship with that point makes with one of the principal directions of the ship (direction of the bow, or of the stern, or of the beam).

The polar bearing of a ship that is being fired upon is also called the *inclination to the plane of fire.*

2. *Sectors of Maximum Offense.*—Let us examine the manner in which the offensive power of a ship varies with the variation of the inclination to the plane of fire.

First of all, let us suppose that the ship under consideration is armed with guns of a single caliber.

By taking into account the fields of fire, the number of the guns that fire in the different directions is determined. The variations of the offensive power may usefully be represented by means of a polar diagram, whereon the principal directions of the ship are traced, and whereon, for every inclination, the radius vector has a length proportional to the number of guns that can fire in that direction.

The offensive field may not be uniform.

The first monitor had two dismountable smoke-stacks; and so the armament, enclosed in a single revolving turret, had a field of fire of 360°.

A type of ship that could satisfy such requirements would secure to the single guns the maximum utilization; but if we establish it as an axiom to consider every ship as an organic unit of the fleet, and then seek to obtain the maximum return from the whole organization, we must admit the necessity of having the

same kind of guns on every ship. This being the case, in order that the offensive field might be uniform, it would be necessary, ideally, to have a number of guns on a circumference, each gun with a field of fire of 180°. The number of the guns being practically limited, there follows the possibility of having some of the guns with a greater field of fire than the one just mentioned, which involves the necessity of the offensive field having its maximums and its minimums.

When long-range combat was held to be only a transitory phase of the action, it was drawn therefrom as a corollary that the maneuvering should be independent of the employment of the guns; therefore it was sought to approximate to a circular arrangement, securing the development of the maximum offensive power in the principal directions of the ship. Thus there was designed for the heavy guns an arrangement on a diagonal (*Duilio*), and in a lozenge, adopted by the French. Thus, also, disposing a battery of medium guns about the sides of a lozenge, given the fact that each gun may fire very close to another situated further inboard, we may say that the above-mentioned object is attained. With arrangements of this nature, if, starting from the beam of the ship, we consider the offensive power developed in the various directions, we find that the maximum power is developed up to a certain angle from the beam; beyond this limit, the power falls to a minimum, it becoming possible to fire only with the guns in one quadrant, until, in the direction of the keel—since there the guns of the other side enter also into action—we have again the maximum offensive potentiality. Thus we have, laterally, sectors of maximum offense and sectors of minimum offense; in the direction of the keel we have a *direction* of maximum offense, but not a *sector*.

At present the power of the artillery compels us to consider the long-range combat as a most important form of action, in which it is necessary to subordinate the maneuvering to the good employment of the guns, without, however, creating too difficult conditions for the maneuvering. From this principle we immediately derive the consequence that simple *directions* of maximum offense badly satisfy the tactical necessities. It is then necessary to direct the mind not so much to the importance of uniformity in the offensive field, as to securing for this field the maximum intensity where most convenient. On this basis it must be re-

membered that, in every discussion of the distribution of the offensive power, the amplitude of the fields of fire of the single guns must serve as basic data only; the important thing is the manner in which the various fields of fire blend together.

Since ships are longer than they are broad, the maximum number of guns can be placed along their length; in such case the result of the distribution of the offensive power still remains, as already mentioned; or, from sectors of maximum offense we pass to those of minimum offense, with a new increase of power when we reach the line of the keel; however, the power in the latter direction is inferior to the maximum. The nearer we approach the arrangement of all the guns on the longitudinal axis, the more we increase the said inferiority, and at the same time we increase the amplitude of the sectors of maximum offense; and, reciprocally, the greater the similarity between the power in line with the keel and that of the sectors of maximum offense, the smaller is the amplitude of the said sectors.

When the armament is composed of guns of different calibers, in order to establish the elements of the distribution of the offensive power that are important in long-range combat, it is evidently necessary to proceed in the following manner: (1) Exclude the guns that are inefficacious in the said form of action; thus, for instance, in battle between armored ships, only the guns above a caliber of about 15 centimeters are to be considered. (2) Determine the sectors of maximum and minimum offense for the calibers that are useful in long-range battle in the manner above mentioned. (3) Observe how the sectors of the various calibers intermingle.

Rigorously, we should hold to be sectors of maximum offense of the ship all those common to the sectors of maximum offense of the various calibers. Their amplitude would hence be determined by the caliber having the most limited sectors; however, it is easy to understand how the amplitude in question may be considered as increased when we take into account the relative importance of the different parts of the armament. In long-range battle the maximum caliber has predominating importance; hence it is its distribution that should essentially be considered. Ordinarily, in the interval between the extremes of the sectors of maximum offense of the maximum caliber, and those of the sectors in which we have, absolutely speaking, the maximum of

power, the variation may be held to be negligible. More in general, by considering the importance that each kind of gun has in the composition of the armament, it will be easy to establish what caliber shall determine the amplitude of the sectors of maximum offense which it will be well to take as the standard in tactical employment.

The search for the best disposition of the guns forms no part of the study of tactics, although it is of consequence to it; for this reason we confine ourselves to simple statements concerning the manner in which the offensive field is distributed in the existing types of ships.

Generally the offensive field is symmetrical with respect to the longitudinal axis * and to the transverse axis.

Dissymmetry with respect to the beam would be advisable whenever we might, with reason, establish a greater probability of fighting with the enemy bearing forward of the beam than abaft the beam, or vice versa; for the present we confine ourselves to noting that we may not exclude the convenience of keeping the enemy abaft the beam, when this is not done in order to avoid action.

In general, between two scouting vessels, one will be interested in bringing about an action, and the other in avoiding it; the tactical maneuvers will thus assume the form of a pursuit. It is not simply a question, as above indicated, of keeping the enemy forward of or abaft the beam, with the object of causing the tactical action to assume the form that we desire, but, more properly, it is a question of chasing or being chased; hence the power of the fire in the direction of the keel will have greater importance than in the types of ships not destined for detached service; this explains why, in the light ships, we seek to obtain directions of maximum offense in line with the keel.

* A dissymmetry with respect to the longitudinal axis would obtain, for example, with two turrets arranged, one on the starboard side and the other on the port side, very near to each other, with their centers in a direction inclined to the said axis, when the guns of one turret are higher than those of the other, so as to permit firing over them; dispositions of this nature would oblige us to present to the enemy a definite side. The study of tactical maneuvering will show us how harmful this limitation may be. (Author's note.)

The types of armored vessels that at present compose the fleet can, on the basis of their armaments, be grouped in the following categories:

(1) *Antiquated ships,* in which the sectors of maximum offense extend about 30° forward of, and about the same distance abaft, the beam.

(2) *Modern ships* (not specially constructed for long-range battle). In these ships the distribution of the fire is about as follows: (a) Maximum intensity in a restricted sector in the vicinity of the beam. (b) Intensity a little inferior to the maximum, and practically to be considered as maximum, in the sectors of 45°-50° forward of and abaft the beam. (c) Minimum intensity in the sectors between the direction of the keel and 45° from the beam. (d) Strong intensity in line with the keel.

(3) *The most modern ships,* that, by the disposition of their armaments, may be divided into two categories: (a) Those with turrets on the longitudinal axis and on the sides, or with a part of them on the axis and a part of them removed therefrom; the sectors of maximum offense, with an amplitude of about 45° forward of, and 45° abaft, the beam, as in the modern ships. (b) With all the turrets on the longitudinal axis; the sectors of maximum offense extend to 55° or 60° forward and abaft, and, as a maximum limit, to 70°.

In the discussion of tactical employment it is therefore necessary to take as a basis the following data: The amplitude of the sectors of maximum offense, in the generality of present-day vessels, is from 45° to 50° forward of and abaft the beam. In some ships this amplitude is 30°, and in others it is 60° forward of and abaft the beam.

3. *Inclination and the Probability of Being Hit.*—Within the limits thus determined for the sectors of maximum offense, we propose to estimate the influence that the inclination of the ship to the plane of fire (which we will count from the beam) has upon the percentage of effective hits made by the enemy.

We may hold, approximately, that the target presented by our ship has a certain uniform height q above the sea, and that its horizontal section is an ellipse, with its axes respectively equal to the length L, and to the maximum breadth l of the ship itself.

Let $PTP'T'$ (Fig. 1) be the section corresponding to the waterline; PP' and TT' being respectively the longitudinal axis and

the transverse axis. If $TON=\psi$ is the inclination to the plane of fire, by projecting on the sea the contour of the upper section of the target, in the direction of the trajectories of all the shots that would touch that upper section, we delineate on the surface of the sea another ellipse which may be held to be identical with the first. The corresponding points of the two ellipses are distant

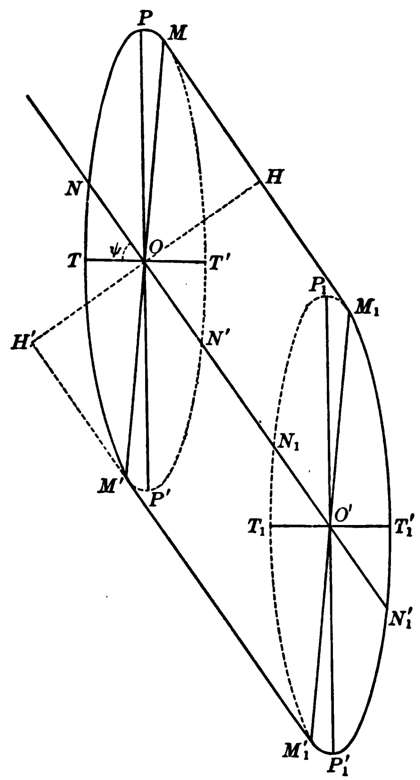

FIG. 1.

from each other $\dfrac{q}{\tan\omega}$, ω being the angle of fall of the projectiles. If MM_1 and $M'M'_1$ are the traces of the planes tangent to the target, drawn parallel to NO, the thin, fictitious, horizontal target, to which we may refer for the question we are discussing, is limited by the portion MNM' of the water-line, by the two segments MM_1 and $M'M'_1$, and by the remaining portion of the ellipse $M_1N'_1M'_1$.

Indicating by $A\psi$ the depth NN'_1 of the fictitious target in the direction of the plane of fire, by the known properties of the ellipse * we have

$$A\psi = NN' + \frac{q}{\tan\omega} = \frac{Ll}{\lambda} + \frac{q}{\tan\omega},$$

making

$$\lambda = \sqrt{l^2 \sin^2\psi + L^2 \cos^2\psi}.$$

The surface $S\psi$ of the fictitious target is given by

$$S\psi = \frac{\pi}{4} Ll + \frac{q}{\tan\omega}\lambda.$$

In regard to the probabilities of hitting, the above-mentioned fictitious target may be replaced approximately by a rectangle with a depth $A\psi$ and a breadth $B\psi$, $B\psi$ being equal to $\frac{S\psi}{A\psi}$.

The probability $p\psi$ of hitting is given by

$$p\psi = p\left(\frac{A\psi}{Ex}\right) p\left(\frac{B\psi}{Ez}\right),$$

Ex and Ez being respectively the longitudinal and lateral stretches in which are included 50 per cent of the shots, and p being taken from the table of the factors of probabilities,† entering the table with the factors $\frac{A\psi}{Ex}$ and $\frac{B\psi}{Ez}$.

* In the equation of the ellipse which has for its axes L and l, substituting for x and y the projections of ON respectively on OP and OT, we deduce

$$NN' = \frac{Ll}{\lambda}. \qquad \text{(a)}$$

The surface $S\psi$ of the thin fictitious target is given by the area of the aforesaid ellipse, and by that of the parallelogram $MM'M_1M_1'$, which is $\frac{q}{\tan\omega} HH'$; HH' being the projection of MM' normally to the plane of fire. The value of HH' is determined as follows:

The area of the parallelogram, which has for its medians two conjugate diameters, is constant and equal to Ll; on the other hand, the area of the parallelogram, which has for medians NN' and MM', is given by $\overline{NN', HH'}$; hence $\overline{NN', HH'} = Ll$; and by equation (a) we find $HH' = \lambda$. (Author's note.)

† With what has been said in this and in the following chapter relative to the probabilities of hitting, it is well to record the following definitions:

The mean of the absolute values of the misses or deviations in a certain direction is called the *mean miss or deviation* in that direction.

The mean deviation, multiplied by the coefficient 1.69, gives the corresponding dimension of the *stretch that includes 50 per cent of the shots.*

If p_0, A_0 and B_0 are respectively the values of $p\psi$, $A\psi$ and $B\psi$ for $\psi=0$ (that is, with the ship placed normally to the plane of fire), making

$$K\psi=\frac{p\psi}{p_0}, \quad K'\psi=\frac{p\left(\frac{A\psi}{Ex}\right)}{p\left(\frac{A_0}{Ex}\right)}, \quad K''\psi=\frac{p\left(\frac{B\psi}{Ez}\right)}{p\left(\frac{B_0}{Ez}\right)},$$

we obtain

$$K\psi=K'\psi K''\psi.$$

For a battle we may not attribute to the 50 per cent stretches the values that are taken from the range tables, but we may establish rational limits that include the values of p. This being the case we note that by entering the table of factors of probabilities with a value $p\left(\frac{A_0}{Ex}\right)$, we may obtain therefrom $\frac{A_0}{Ex}$, which, multiplied by $\frac{A\psi}{A_0}$, gives us $\frac{A\psi}{Ex}$, with this argument, we obtain from the table above mentioned, p $\left(\frac{A\psi}{Ex}\right)$, which, divided by $p\left(\frac{A_0}{Ex}\right)$, gives us a value of $K'\psi$. We obtain $K''\psi$ by an analogous operation.

The values of $\frac{A\psi}{A_0}$ and $\frac{B\psi}{B_0}$ are functions of ω. Rigorously, for applying the indicated process, we ought to know the distances corresponding to the considered values of $p\left(\frac{A_0}{Ex}\right)$ and $p\left(\frac{B_0}{Ez}\right)$; however, this is not necessary because, within the limits between which ω may oscillate, for the various kinds of guns, in long-range battle, we find practically that the variations of $\frac{A\psi}{A_0}$ and $\frac{B\psi}{B_0}$ are restricted in such fashion that we may assume for

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The mean deviation multiplied by the coefficient $1.69:2=0.845$, gives the corresponding probable mean error, which is greater than one-half of the errors and less than the other half.

The mean probable error produced by the simultaneous action of sundry independent causes is given by the square root of the sum of the squares of the mean probable errors. (Author's note.)

these quantitties a mean value for every value of ψ within the limits of 0° and 70°.

Such being the case, for a ship that has the dimensions

$$L=150 \text{ meters}, \quad l=25 \text{ meters}, \quad q=8 \text{ meters},$$

supposing that the probability of direct hits in long-range battle may vary between 10 per cent and 50 per cent, we obtain for these limits the following

VALUES OF $K'\psi$.

Probabilities.

ψ	10 per cent.	50 per cent.	Mean.
0°	1	1	1
30°	1	1	1
45°	1.10	1.10	1.1
60°	1.25	1.18	1.2
70°	1.60	1.46	1.5

As is seen, the values of $K'\psi$ corresponding to the two limits of probability are about equal; we may therefore consider their mean.

For the supposed dimensions of the ship, the above values of $K'\psi$ express also the values of $K\psi$, within the limits of distance in which the width of the target is so much superior to that of Ez as to enable us to hold $K''\psi=1$.

When $B_0=4Ez$ (that is to say, when there is a probability of 1 with respect to the ship that presents her beam) we obtain the values of $K''\psi$ indicated in the following table; and hence, multiplying the values of $K''\psi$ by the corresponding values of $K'\psi$, we have the values of $K\psi$.

ψ	$K''\psi$	$K\psi$
0°	1	1
30°	1	1
45°	0.9	1
60°	0.8	1
70°	0.6	0.9

At the greatest distances an important lateral dispersion is inevitable. Under the not exaggerated hypothesis that out of 100 shots we may have 80 good in direction, we obtain

ψ	$K''\psi$	$K\psi$
0°	1	1
30°	0.9	0.9
45°	0.8	0.9
60°	0.6	0.7
70°	0.4	0.6

Hence we draw the following deductions:

(1) Within the limits of distance in which there is certainty that all the shots will be good in direction, the probability that the ship will be hit increases almost insensibly with ψ varying from $0°$ to $45°$, and afterwards it increases rapidly.

(2) Within the limits of distance in which the above-mentioned certainty is had only when the ship presents her beam, the directions included in the sectors of maximum offense are unimportant in so far as the probability of the ship being hit is concerned.

(3) At the greatest distances, the directions that are not removed more than $45°$ from the beam may still be considered unimportant with respect to the probability of the ship being hit; this probability undergoes a notable diminution at the extreme limits of the sectors of maximum offense of ships with all the heavy guns located on the longitudinal axis.

It is moreover to be noted that, in the hypothesis that for $\omega = 10°$, we have $p\left(\frac{A_0}{Ex}\right) = 10$ per cent, $p\left(\frac{B_0}{Ez}\right) = 80$ per cent, for $\psi = 90°$, or when the ship presents herself end on, we have $K'\psi = 2.6$, $K''\psi = 0.2$; and hence, $K\psi = 0.5$; which, compared with the other values of $K\psi$ already calculated, shows that, *at the maximum fighting distances, a ship that presents herself end on, diminishes in that way the percentage of the enemy's effective hits.*

The preceding deductions avail for the hypotheses that may be made concerning the dimensions of battleships.

4. *Inclination and Protection.*—When it is said that a certain gun is capable of perforating a given thickness of vertical armor at a given distance, it is with reference to the hypothesis that the projectile arrives in a horizontal direction, normally to the plate, and that the latter is exactly vertical. As is well known, in battle, in the most favorable case for the gun, that is, when the plane of fire is normal to the plate, the conditions differ from those above stated for the following principal reasons: (1) The divergence of the axis of the projectile (supposed to be coincident with the direction of movement) from the normal to the plate, owing to the angle of fall and to the oscillatory movement of the target. (2) The divergence of the axis of the projectile from the direction of its movement. (3) the elasticity of the entire hull, which forms one body with the armor. We deduce from this that, in battle, a plate normal to the plane of fire is capable of resisting a

projectile that, with the same velocity of impact, would perforate it under the conditions of trial at the proving grounds. With reference to the battle, the hypothesis that the projectile arrives horizontally, with its axis coincident with the direction of movement, may then be taken into consideration; observing, however, that the results that are deduced therefrom have reference to limit conditions of efficacy of the projectile, that is to say, to ideal conditions, not attainable.

This being understood, if, under the proving ground conditions, and with the plane of fire normal to the plate, a projectile animated by a velocity of impact v is capable of perforating a thickness of armor s, on the other hand, when the plane of fire is inclined to the normal by an angle, ψ, the perforable thickness is s_i, less than s; and this does not depend solely upon the fact that there is disposed normally to the plate only a component of the velocity, but also upon the greater distance that the projectile must travel in the plate itself. This being the case, we may hold that the conditions of oblique impact are equivalent to those of normal impact with a velocity of impact $v \cos h\psi$, where h is an opportune coefficient.

Applying the De Märre formula for perforation successively to the case of normal impact and to that of oblique impact, and indicating by F the product of the terms of said formula, independently of the thickness of the plate and of the velocity of impact, we have

$$v=Fs^{0.7},$$
$$v=\cos h\psi=Fs_i^{0.7};$$

and hence

$$s_i=s(\cos h\psi)^{\frac{1}{0.7}}.$$

In order to establish the value of h, let us note first of all that, concerning oblique fire, the data are scant and the formulas are uncertain. It appears to be proved that the cap of the projectile may have among its advantages that of approaching the axis of the projectile to the normal to the plate; and hence, for moderate values of ψ, it seems that we may hold $h=1$. With the increase of ψ (that is to say, when the obliquity of fire is greater), the efficacy of the cap diminishes, and the perforable thickness s_i is less than that obtained by making $h=1$. Consequently *it is logical to admit that h may be a function of ψ*. For $\psi=60°$ the rebounding of the projectile is realized (when the thickness of

the plate is not excessively less than the caliber of the projectile), and hence $v \cos(h\, 60°) = 0$; from which $h = 1.5$.

Admitting that h varies proportionally from the value of $h = 1$, which corresponds to $\psi = 0$, to the value $h = 1.5$, corresponding to $\psi = 60°$, we obtain with the formula above mentioned the following table:

ψ	$\frac{s_t}{s}$
10°	0.98
20°	0.88
30°	0.72
40°	0.49
45°	0.35

If the values of s refer to limit conditions of efficacy of the projectile, the same may be said for the corresponding values of s_t; in other terms, as the thickness s—which, with a certain velocity of impact, is perforable on the proving ground—is more than sufficient to prevent penetration during battle, analogously, for an obliquity ψ the same result is obtained with a thickness s_t whose ratio with s is about that indicated in the table.

This shows the desirability of presenting the armor obliquely to the fire. Bearing in mind the perforating capacity of modern heavy guns, on the basis of the results above set forth—although we are far from pretending that they are rigorously exact—we may affirm that, for a ship which has on its sides armor of a thickness of 150 millimeters or greater, there are directions included in the sectors of maximum offense from which the armor cannot be pierced.

Let us suppose the case that we have on the sides a uniform thickness of armor not less than 150 millimeters. *The direction nearest the beam in which the side is invulnerable to the enemy's most powerful gun,* while it permits the development of the maximum offensive power, is that to which, with regard to the armor, the maximum defensive capacity corresponds; indeed, in the directions nearer to the beam the perforation of the side is possible. By approaching further toward the longitudinal axis the effects of the enemy's fire increase—it becomes an enfilading fire.

In the case of different thicknesses of armor, *the defensive capacity is maximum when the enemy bears in the direction nearest the beam in which the vulnerability of the side is minimum;* and this direction is determined with reference to the minimum thick-

ness of armor that covers a considerable surface on the side; when, however, such thickness is not below a certain limit, which may be held to be about 150 millimeters. As to armor of less thickness, it should be held to be a useless burden, since it could not possibly prevent perforation.

In order to fix these ideas we may distinguish two cases:

(1) If the ship under consideration carries at the water-line a belt which has, over a considerable stretch, a thickness greater than 150 millimeters, and above has only thin armor, or if also above the belt the thickness of the armor is greater than 150 millimeters, the maximum defensive capacity may be held to be obtained in the directions inclined about 30° to that of the beam.

(2) If the ship has on its sides large extensions of armor with a thickness of about 150 millimeters, the maximum defensive capacity is obtained in the directions about 45° from the beam.

5. *Directions of Maximum Utilization.*—When a ship is opposed to another in long-range battle, it is said to have the other bearing in a *direction of maximum utilization* if it is inclined, with respect to the line joining it with the adversary, in such fashion as to enable it to use the maximum offensive power, while at the same time presenting itself also under the best defensive conditions.

What we have set forth demonstrates the existence of such directions, and precisely permits us to conclude:

(1) At the maximum fighting distances (between 8000 and 10,000 meters) the directions of maximum utilization are those of the extremes of the sectors of maximum offense.

(2) At inferior distances the directions of maximum utilization are those to which the maximum defensive capacity of the armor corresponds.

Naturally it is not intended to establish the rule that a ship must always keep the enemy bearing in one of the four directions of maximum utilization that are determined in this way; it is only insisted that these directions constitute *an element of the highest importance for tactical maneuvering.*

CHAPTER II.

RADIUS OF ACTION OF THE TORPEDO.

6. *Conditions of the Problem.*—The introduction into use of torpedoes having a speed of 31 knots an hour over a run of

nearly 6500 meters is announced; in what we say we shall have reference to this advanced type of weapon.

The inferior limit of long-range combat is given to us by the radius of action of the torpedo, the determination of which is therefore indispensable in order to proceed with the study of the tactics; the more so since the improvements in the torpedo seem to give reason for the belief that this weapon has almost completely invaded the field of the gun. It appears permissible to think so for the following reasons:

(1) The increase in the tonnage of battleships implies that they may be very long in order to enable them to reach high speeds.

(2) The launching distance may be greater than the run of the torpedo when the ship attacked is moving in the direction of the torpedo.

(3) Conceding that there may be scant probability of success in launching from a great distance against an isolated ship, we may at any rate rely upon the launching of torpedoes against an assemblage of ships.

It is of interest to estimate the importance of these matters, taking as a basis the following axiom: "A weapon, the action of which cannot be repeated except at considerable intervals of time, and of which the supply is very limited, must be employed only under conditions that may assure a notable probability of hitting." *

7. *Relation Between the Length and the Duration of the Run.* —The engine of the torpedo is devised for the maximum speed. Since we desire to determine the radius of action of the torpedo, admitting that this weapon may realize the best requisites to-day conceivable, let us suppose that the type of torpedo capable of running over 6500 meters at an average speed of 31 knots an hour, may have as a maximum speed per hour about 50 knots; and let us seek a relation that, within these limits of speed, may

* On the basis of this axiom, when the heavy guns had a very slow rate of firing, they were justly held to be unadapted for employment at the maximum fighting distances; these same cautions are to-day imposed upon the employment of the torpedo. Although there exists the possibility of a lucky hit when launching the torpedoes with small probability of hitting, we must keep in mind the necessity of being ready to launch when, owing to the closing of the distance, the probability of hitting is greatly increased. (Author's note.)

permit us approximately to calculate the duration of the run as a function of its length.

Let c be the length of the run expressed in meters; v the corresponding speed in meters per second; $t=\frac{c}{v}$, the duration of the run.

The ratio between the weight of air consumed during the run and the duration of the run itself, expresses the consumption of air in one second.

The weight of air consumed during the run is the difference between that which is contained in the charged tank, and that which remains therein at the end of the run. The latter is greater the higher the working pressure. Consequently, if, after a run of less than 6500 meters, we suppose the tank to contain the same weight of air that remains therein after a run of 6500 meters, we commit an error, by virtue of which, for a given speed, we shall be led to attribute to the torpedo a run greater than the actual run. Under the supposition mentioned, indicating by A the quantity of air consumed during the run, a and a_0 being the amounts consumed in 1 second corresponding to the times t and t_0, we have

$$a=\frac{A}{t}, \quad a_0=\frac{A}{t_0},$$

and hence

$$\frac{t}{t_0}=\frac{a_0}{a}.$$

F and F_0 being the indicated horse-powers for the speeds v and v_0, corresponding to t and t_0, the value of $\frac{a}{F}$ (that is to say, the consumption per horse-power in 1 second) continually increases the more the speed differs from that for which the engine was designed. In supposing that

$$\frac{a}{F}=\frac{a_0}{F_0};$$

if a_0 and F_0 refer to the maximum run, we thereby commit an error which, for a given speed, would lead us to attribute to the torpedo a run shorter than the actual run.

Taking the two preceding hypotheses together, that is, holding that

$$\frac{t}{t_0}=\frac{F_0}{F},$$

we are able to admit that the two errors mentioned may compensate each other. As, on the other hand, we may hold that the power varies approximately as the cube of the speed, we obtain

$$\frac{t}{t_0}=\left(\frac{v_0}{v}\right)^3.$$

By means of this equation, knowing by experiment that v_0 corresponds to t_0, we can deduce the time t for a speed v. Letting c and c_0 be the runs corresponding to t and t_0, we have

$$v_0=\frac{c_0}{t_0}, \quad v=\frac{c}{t},$$

and, substituting in the preceding equation, we obtain

$$t=t_0\left(\frac{c}{c_0}\right)^{\frac{3}{2}},$$

which is the equation sought; it shows that the duration of the run varies approximately as the   power of the run of the torpedo.*

* To prove that the formula thus found is sufficiently trustworthy, we have recourse to the data of the experiments carried out in 1897 by Makaroff, who was the first advocate of long distance launching (*Cfr. Questioni di Tattica Navale,* trad. Saint-Pierre). Taking for c_0 and t_0 the values relative to the greatest run, we here set down the experimental and the calculated results:

c (experimental)	Speed per hour	t	c (calculated)	Errors
(meters)	(knots)	(seconds)	(meters)	(meters)
2774	11	504	....	....
2134	14	305	1985	− 149
1280	18	142	1192	− 88
640	23	55	633	− 7

For a modern type of torpedo we refer to data supplied by "Engineering" of Feb. 14. 1908, concerning the 18-inch, hot-air, Whitehead torpedo:

c (experimental)	Speed per hour	t	c (calculated)	Errors
(meters)	(knots)	(seconds)	(meters)	(meters)
3656	28	261	....	....
2742	32	171	2766	+ 24
1828	38	96	1877	+ 49
1371	40	68	1491	+ 120
914	43	42	1072	+ 158

(Author's note.)

Putting $c = 6500$ meters, $t = \frac{6500}{15.5} = 419$ seconds (15.5 being the speed in meters per second corresponding to that of 31 knots per hour), we obtain the formula

$$t = 0.0008c^{\frac{3}{2}},$$

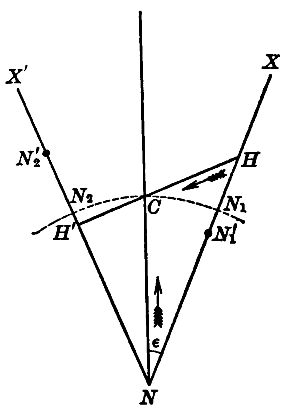
with which the following table is calculated:

c (meters)	t (seconds)	speed per hour (knots)
6500	419	31
6000	372	32
5500	326	33
5000	283	35
4500	242	37
4000	203	39
3500	166	42
3000	131	46
2500	100	50

8. *The Case of Two Vessels Opposed to Each Other.*—Let us determine successively: (1) The consequences of an error in the estimation of the direction in which the target is moving. (2) The consequences of an error in the estimation of the speed of the enemy.

(1) Evidently, an error $\pm\epsilon$ in the estimation of the course of the target would be included in a sector having an amplitude 2ϵ; the probability of hitting resulting from this for the torpedo will be so much the greater the nearer the torpedo's track approaches to a direction perpendicular to the bisector of the said angle 2ϵ. For the purpose which we propose for ourselves, it will be sufficient to refer to the case of a perpendicular impact.*

* Let XNX' be the sector with an amplitude 2ϵ which has for its vertex the position N of the ship at the moment of launching the torpedo; HH', the track of the torpedo, which accordingly has a forward angle of impact. If the course of the ship were NC, the torpedo would strike it at C. If, instead, the course were NH, at the moment at which the torpedo is at C the ship is on the arc of a circle with its center at N and with a radius, NC, which cuts the lines NX and NX' in the points N_1 and N_2 respectively; consequently on the arrival of the torpedo at the points H and H', the ship will be respectively at positions N'_1 and N'_2. The mean miss



Let N (Fig. 2) be the position of the ship at the moment at which the torpedo is launched, which torpedo would strike the center of the ship at C when the ship follows the track NC, normal to the path HC of the torpedo. If, instead, the course were NH, deviating by an angle ϵ toward the launching tube, in the time t in which it would have arrived at C, the ship will be in a position, N_1, such that $NN_1 = V_N t$; V_N being the speed of the ship in meters per second.

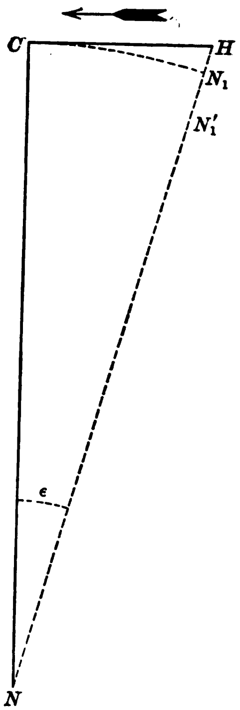


FIG. 2.

The ship will then be at a distance

$$N_1H = NH - NN_1 = V_N t\left(\frac{1}{\cos\epsilon} - 1\right)$$

from the point H at which the course crosses the track of the torpedo.

But the torpedo arrives at H at an instant which precedes that of the arrival of the ship at N_1 by an interval of time, $\frac{CH}{v}$; hence, when the torpedo is at H, the ship will be at a point, N'_1, such that

$$N'_1N_1 = \frac{CH}{v}V_N.$$

CH being equal to $tV_N \tan\epsilon$, if we indicate the amount of the miss by s, there results, then,

$$s = N'_1H = V_N t\left(\frac{1}{\cos\epsilon} - 1 + \frac{V_N}{v}\tan\epsilon\right).$$

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will hence be

$$\frac{N'_1H + N'_2H'}{2}.$$

It is readily seen that the nearer HH' is to being perpendicular to NC, the smaller are N'_1H and N'_2H'; therefore the mean miss diminishes and the probability of hitting increases.

It is now necessary to bear in mind that the particles of water which accompany the ship in its movement, in the case of a forward angle of impact, tend to place the torpedo perpendicular to the ship, or to insure the functioning of the firing pin; while in the case of an angle of impact abaft, the torpedo tends toward a course parallel to that of the ship. Therefore it must be held that the ideal condition for the torpedo is that with an angle of impact of 90°, because to that angle there corresponds a mean miss less than for a forward angle of impact, and there is no doubt of the functioning of the weapon. (Author's note.)

Considering ϵ to be negative in the case in which the course deviates toward the side opposite that of the launching tube, the preceding formula expresses in a general way the value of s, which is negative when the torpedo passes abaft the center of the target.

Indicating the length of the ship by L, in order that there may be a certainty of hitting the target, we must have $s \leqq \frac{1}{2}L$.

With $L = 200$ meters, $V_N = 10$ meters per second and $c = 6500$ meters, we have

$$s = \pm \tfrac{1}{2}L \quad \text{for} \quad \epsilon = \pm 2^\circ \text{ (about).}$$

But we can have no confidence in being able to estimate the course of the ship * with a mean error less than 10°.

Always, for $V_N = 10$ meters per second, with the values of t and v that correspond to the maximum run of 6500 meters, we get

$$\left.\begin{array}{ll} \text{for } \epsilon = +10^\circ, & s = +536 \text{ meters} \\ \text{for } \epsilon = -10^\circ, & s = -411 \text{ meters} \end{array}\right\} \text{a mean miss of 473 meters.}$$

With $c = 3000$ meters, we get

$$\left.\begin{array}{ll} \text{for } \epsilon = +10^\circ, & s = +119 \text{ meters} \\ \text{for } \epsilon = -10^\circ, & s = -80 \text{ meters} \end{array}\right\} \text{a mean miss of 99 meters.}$$

With $c = 2500$ meters,

$$\left.\begin{array}{ll} \text{for } \epsilon = +10^\circ, & s = +85 \text{ meters} \\ \text{for } \epsilon = -10^\circ, & s = -55 \text{ meters} \end{array}\right\} \text{a mean miss of 70 meters.}$$

Hence, as the maximum value that we can suppose for L is 200 meters, we are justified in stating that, *beyond the limit of 3000 meters of run, the mean miss due to the error in the estimation of the enemy's course cannot be considered as less than half the length of the target.*

* It is to be noted that, until the recent improvements in the torpedo, there were admitted, as the mean errors in the course and in the speed of the target, the values of 10° and 2 knots respectively, reference being had to runs of about 1000 meters. With the increased runs, it is logical to recognize that the difficulties of estimating the movement of the target are increased; nevertheless, let us still hold the above mentioned values for the mean errors, so that, in this way, the correctness of our reasoning may be proved *a fortiori*.

(2) When an error, Δ, is made in the estimation of the speed of the enemy's ship, the miss s of the torpedo will be equal to the space passed over by the ship in the time t with a speed, Δ; or

$$s = \Delta t = \Delta \frac{c}{v}.$$

With an error, Δ, in order that the ship may be hit it is necessary to have

$$t \leqq \frac{\frac{1}{2}L}{\Delta}.$$

We can have no confidence in being able to estimate the speed of the enemy's ship with an error less than 2 knots; therefore, putting $\Delta = 1$ meter per second, and supposing that $L = 200$ meters, we must hold that $t = 100$ seconds is *the maximum duration of the run, with which the mean miss, due to the error in the estimation of the enemy's speed, does not exceed half the length of the target.*

In order to secure such a result with a run of 6500 meters, it would be necessary to have a corresponding torpedo speed of 65 meters per second; that is to say, a speed per hour of 130 knots, which we are very far from realizing.

Under the hypothesis of launching a torpedo against an isolated ship, this is well recognized, whatever may be the character of the improvements made in the torpedo; while the improvement in the gun is apparent when there is obtained, for a given caliber and at a certain distance, a residual velocity that previously was only obtained at a shorter distance, for the torpedo, instead of equality, we must have an increase of speed.

From the table in section 7 it is seen that $t = 100$ seconds corresponds to $c = 2500$ meters. For this run, the mean probable error due to the combination of the errors in the course and in the speed of the target will therefor be

$$s = 0.845\sqrt{70^2 + 100^2} = 103 \text{ meters}.$$

It is well to bear in mind: (1) That the miss calculated for the errors in the course has reference to the most favorable conditions for the torpedo. (2) That the torpedo is affected by a multiplicity of accidental causes of misses. In consequence of which we may hold that this weapon can have a sufficient probability of hitting an isolated ship, only when the mean probable

error depending upon the errors in the course and in the speed of the target, does not notably exceed the value of $\frac{1}{2}L$, which corresponds to a probability of hitting of 50 per cent.

It seems, then, that we may logically affirm that *the actual profitable run of the most improved torpedoes cannot be set down as greater than 2500 meters.*

Since, as is well known, the angle of 30° may be held to be the minimum angle of impact of the torpedo, the maximum launching distance SN (Fig. 3) against a ship in a position, N, with a

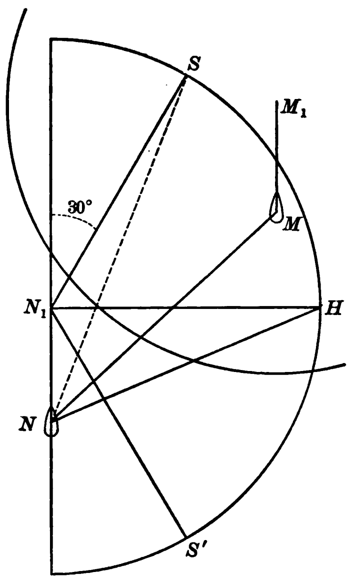


FIG. 3.

speed $V_N = 10$ meters per second, may be obtained by constructing a triangle, NN_1S, in which

$$NN_1 = V_N t = 1000 \text{ meters},$$
$$NN_1S = 150°,$$
$$N_1S = 2500 \text{ meters}.$$

From this triangle we find $SN = 3400$ meters.

Let it be noted that the speed supposed for N is not small, and that the launching distance would be less than that obtained whenever N might have S bearing in a sector of maximum offense of the guns. We may therefore affirm that, in the case

of an isolated ship, the radius of action of the torpedo is to be set down as less than 3500 meters; or in other words, *beyond the distance of 3500 meters from the enemy, a ship may maneuver without troubling itself about torpedoes.*

9. *The Danger Zone* (Fig. 3).—The geometrical locus of the positions from which torpedoes may be launched to strike the ship after a run, c, is obtained by making $NN_1 = V_N t$, describing a circle with its center at N_1 and with a radius c, and then limiting to the right and left of the ship, the arcs—as SS'—included between the two straight lines passing through N_1, and which form angles of 30° with the course.

Any such circle includes within itself the circles corresponding to shorter runs. Indeed, the difference $c - V_N t$ diminishes with t; and hence, indicating by c' and t' two other corresponding values of the length and the duration of the run, when $t' < t$ we shall have

$$c - c' > V_N (t - t').$$

The difference between the radii of the two circles considered is therefore greater than the distance between the centers; or, the two circles have no points in common.

The circle traced for the greatest run to which corresponds a sufficient probability of hitting, therefore includes *the danger zone* with respect to the torpedoes.

The eccentric position of the ship in this zone so determines matters that a combatant may find himself within the radius of action of the enemy's torpedoes, without having the enemy within the radius of action of his own torpedoes. Thus, in Fig. 3, the ship N has the enemy M in his danger zone, while it is itself outside of the zone of M (which has a center at M_1, such that $MM_1 = NN_1$). This leads to the establishment of *the preference that is possibly to be given to bearings abaft the beam,* in the field of the torpedo.

10. *Concentration of Torpedoes.*—The circle, traced as above described for the maximum run of the torpedo (6500 meters), limits the danger zone for the concentration of torpedoes. This zone is greatly extended forward of the ship's beam; indeed, the launching distance NS, corresponding to the minimum forward angle of impact, is even slightly greater than 10,000 meters, for the ordinary speed of 20 knots per hour, which, at present, it is well to hold as the mean battle speed.

By virtue of what has been said in section 8, we observe that, at the limit of this danger zone, the percentage of effective torpedo hits is very small. We have seen, in fact, that to a mean error of 10° in the course of the target, there corresponds a mean miss of 473 meters; and that for an error of one meter per second in V_N we have a mean miss of 419 meters; hence, the probable mean error that must be reckoned upon in virtue of the two partial errors aforesaid, is 534 meters. The 50 per cent stretch is thus 1068 meters, and the percentage of effective hits against a ship 200 meters long, is, then, 10 per cent.

On this basis, there would appear to be rational a concentration, which, however, should be executed with at least five torpedoes; thus having the probability of obtaining the result that may be expected from a single torpedo, launched for a run of 2500 meters.

This cannot be accepted unconditionally; in fact, the above mentioned value of the miss, due to the error in the course of the target, has reference to the hypothesis of a perpendicular impact. The miss increases with the obliquity of the impact, and besides, it must be remembered that, with the same length of run for the torpedo, the error committed in the estimation of the course and of the speed is evidently greater the greater is the launching distance.

It seems logical, then, to admit the possibility of having, with a run of 6500 meters, 10 per cent of effective hits, when, however, the impact is normal.

The position *H*, from which a hit with normal impact can be made with a run of 6500 meters, is found to be at a distance of 7500 meters from the ship.

It is clear that, from this distance, the ship *N* can render impossible the concentration of the torpedoes of several ships by means of an opportune hindrance of their maneuver; so disposing that the enemy's line may not be a secant of the danger zone in the segment occupied by the formation.

This hindrance may be determined by deducing graphically the maximum launching distances for the different bearings from the ship's head, which permits fixing the idea in the following manner: In order to have the certainty of rendering impossible the concentration of torpedoes, the enemy's ships must not be brought to bear at less than a certain angle from the bow, which

angle is respectively 60°, 90° and 120°, for ships distant about 7500, 4500 and 3500 meters.

It is well to observe that, for the concentration of torpedoes, two conditions are required: (1) The line of formation of the ships launching the torpedoes must be suitably inclined with respect to the line joining it with the adversary.

(2) The course of the latter must be favorable to the launching, and it must be kept exactly constant for the duration of the run of the torpedo; a duration that, for long runs, is very considerable.

Since, in a combat between battleships, we cannot, as in the attack of torpedo boats, count upon a surprise for taking up an advantageous position, it is not very probable that the two conditions above mentioned can be realized at one and the same time.

It seems allowable, then, to conclude that, although the concentration of the torpedoes of several ships may not be absolutely prevented within the radius of 7500 meters (and this renders it advisable not to bring the enemy to bear in the neighborhood of the bow), still, there is no great cause for apprehension concerning it; and, reciprocally, it is not well to rely too much upon this employment of the weapon.

11. *Launching Against an Assemblage of Vessels.*—As is well known, on the basis of the theory of probabilities, a target, the extent of which in a certain direction is four times the length of the 50 per cent stretch, includes all the shots.

In the preceding section, it is seen that a 50 per cent stretch, about 1000 meters long, corresponds to the maximum run of the torpedo; consequently, all the shots are included in a formation that extends at least 4000 meters normally to the mean track of the torpedoes.

The launching must be directed to strike the center of the formation; and, naturally, from what has just been said, its success must depend upon the course of the ships attacked, with a probability that the track of the torpedo may cut the formation in one of the vacant spaces. It is well to note that, for formations in single line and at a distance of 500 meters between the centers of two adjacent ships, in the most favorable case of $L=200$ meters, the said vacant spaces amount to about three-fifths of the total line.

Hence, we may not exclude the case that some ship may be in a position for launching with a fair probability of hitting, but it

is not well to rely upon launchings by several vessels against the enemy's assemblage, unless the formation of the latter is of extraordinary length, or unless he adopts a bow and quarter-line formation, and unless his course is favorable.

In employing torpedoes, either with a view to concentration or when considering the enemy's fleet as a single target, it is well to bear in mind that we face the following dilemma: either we launch from a long distance and very probably only waste torpedoes, or we launch from a distance somewhat greater than the limit established for the case of two ships opposed to each other, and so run the risk of being found unready to launch them within the really effective radius of the weapon, should the distance rapidly be shortened in an unforeseen manner.

In conclusion, beyond the range of 3500 meters determined in section 8, the employment of the torpedo may not be excluded, but is only occasional; so that, from the point of view of the defense, there is no occasion to trouble oneself very much about it; and from that of the offense, it is well not to sacrifice, even in a minimum degree, the employment of the gun.

CHAPTER III.

ADVANTAGEOUS POSITIONS.

12. *Alignments.*—The formation of a fleet of ships is defined by the lines joining the units of the formation, and by the angles that these lines make with the direction of movement.

The study of tactics cannot be reduced to that of fixed formations, the importance of each single formation not being absolute but relative to the situation of the moment.* The idea, then, that the formations are to be considered as consequences of the maneuvers, having the objective of acquiring or maintaining determined relative conditions of position with respect to the enemy, must be held to be fundamental. From this arises the necessity of fixing in the mind the advantageous positions in long-range combat, and of doing this in a way that, as far as possible, may be independent of the formations.

* "C'est moins l'ordre qui a de l'importance, que la position relative des combattants; . . . . tout l'effort doit tendre à donner à ses forces une position de combat favorable." Daveluy, *L'esprit de la guerre navale—La tactique,* 1909.

In order to obtain such maximum generality of reasoning, it is principally necessary to have reference to the relative position of the lines of the enemy's formation, supposing the inclination of the ships on their respective lines to be variable.

Naturally, it is necessary to take into account the length of the various segments of the line occupied by each party. To the geometrical figure composed of these segments we will give the name of *alignment* (*schieramento*).

A few definitions are necessary concerning the various kinds of alignment that it is well to distinguish, in relation to the hypotheses that we shall have to consider.

We say that a naval force has a *double alignment* when its ships are arranged on two adjacent parallel lines; the alignment of a naval force is *simple* when it is in single line.

Alignments may be rectilinear and curvilinear; we will call *angular* the alignments composed of two rectilinear segments that are not prolongations of each other.

When a naval force maneuvers by separate groups, by *alignment of the naval force,* we mean that composed by the segments that join the centers of the single groups; the alignment of each group being defined in the manner above stated.

By *the inclination of a rectilinear alignment* we mean the angle formed by the alignment and the line joining its center with the center of the enemy's alignment.

13. *Zones and Sectors of Offense.*—In order to fix these ideas, let us first of all suppose that we have, in column of vessels (Fig. 4), a naval force composed of ships whose sectors of maximum offense extend 45° forward of and 45° abaft the beam. It is clear that if we draw from the leading ship the straight lines *AH, AH′,* making angles of 45° from the bow; and from the rearmost vessel the straight lines *CK, CK′,* making angles of 45° with the direction opposite that of the course, these lines, and the length of the formation, limit the zones *HACK, H′ACK′,* which are those of maximum offense, when, however, the ships do not all fire at one and the same target.

Rigorously, from the above-mentioned zones it would be necessary to subtract those of minimum offense, *ADB, BEC, ... ,* but it is evident that these need not be taken into account except at short distances.

The said zones *HACK, H'ACK'*, and the corresponding sectors of minimum offense, *HAH', KCK'*, refer to the case of *the distribution of the fire;* while it is evident that, under the hypothesis of the *concentration of the fire,* the sectors of minimum offense—for the formation under consideration—are wider, and the zones of maximum offense are more restricted.

As, for a ship, we distinguish the sectors of maximum, and those of minimum offense, so, for any formation, there exist *zones of maximum offense,** and *sectors of minimum offense.*

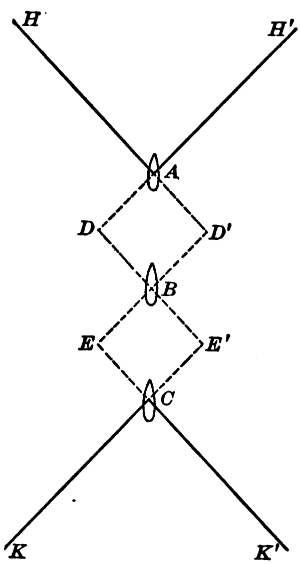


FIG. 4.

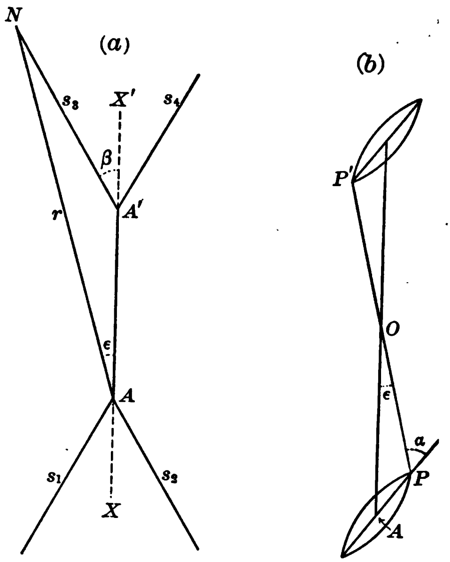


FIG. 5.

If, instead of to a special formation, we refer to the alignments in general, the amplitude of the zones of maximum offense are determined, taking into account the inclination of the ships which is most opportune for diminishing the amplitudes of the sectors of minimum offense. With this object, given a simple rectilinear alignment, *AA'* (Fig. 5a), the inclination just mentioned is determined by the limit condition that each ship, firing in an extreme

* We say *zones,* and not *sectors,* as in the case of a ship, because, if the ship may tactically be considered as a point, the length of the formation is anything but negligible. (Author's note.)

direction of a sector of maximum offense (the angle which this direction makes with the longitudinal axis we will call α), tangents the ship adjacent. Indicating by ϵ (Fig. 5b) the angle thus made between the alignment and the direction of the plane of fire, with d as the interval between ships and with L as the length of each ship, from the triangle OAP (O being the point in which the alingment intersects the line PP' joining the extremities of two adjacent ships) we have

$$\frac{\sin \epsilon}{AP} = \frac{\sin \alpha}{OA},$$

and hence

$$\sin \epsilon = \frac{L}{d} \sin \alpha,$$

from which, with the mean data ($L = 150$ meters, $d = 500$ meters, $\alpha = 45°$), we obtain $\epsilon = 12°$; for safety's sake let us say $\epsilon = 15°$.

From this it follows that, if we draw from the extremities of the alignment four right lines forming angles of 15° with the prolongation of said alignment, we determine the zones of maximum offense and the sectors of minimum offense; in the case, however, in which it is not required that the offense of several ships shall converge upon one and the same target.

When this last condition is established, it must be borne in mind that, beyond a certain limit, the greater the number of ships that take part in the concentration, the smaller is the effect of the firing.

This diminution of effect cannot be considered if the concentration is evidently imposed by special conditions of position; but, in general, it is necessary to limit the number of ships destined to fire at one and the same target.

There is no difficulty in admitting that the fire of three or four ships may be concentrated. Without entering into the methods for the control of the firing during concentration, one datum to be remembered is that Togo, who at Tsushima had 12 armored ships, has written in his report that he concentrated his fire upon two of the enemy's units; hence it seems permissible to believe in the concentration of the fire of six units also, and, without experience to the contrary, it is well to hold this number of units to be the maximum.

On this basis, in the case of the concentration of the fire, it is well to consider the alignment as divided into elementary parts,

each having the length $(n-1)d$; n being a number of ships not greater than six. AA' (Fig. 5a) being one of these parts, we form the triangle $AA'N$, wherein $NAA'=\epsilon=15°$, and N indicates the position of a hostile ship at a distance $r=NA$ from the most distant point of AA'. Indicating by β the angle $NA'X'$ formed by NA' with the prolongation of the alignment, it is clear that the lines s_1, s_2, s_3, s_4, drawn from A and A', making angles β with AX and $A'X'$ respectively, determine the zones of maximum offense for the supposed value of r.

With a value of r anywhere between 10,000 meters and 6000 meters, β is about 20°; and the difference $r-r'$ is about 2000 meters (r' being the distance of N from the nearest point of AA').

14. *Concentration and Distribution of the Fire.*—Let us suppose that one of the combatant parties, which we will indicate by C, concentrates his offense; while the other, which we will call R, directs the offense of each ship against a ship of the adversary. The party C secures tactical and strategical advantages, because R is hampered in his movements owing to one of his units having the sum of all the injuries that, on the other hand, are distributed among the different units of C. It would then appear logical to establish the concentration of fire as a tactical objective, executing this concentration successively upon the various units of the enemy, changing the object of concentration whenever one is put out of action. Thus, one group of ships, with respect to another hostile group, should concentrate the offense upon one ship; and several groups should endeavor to concentrate their offense upon one and the same group of the enemy.

This seems to be confirmed by history. Indeed, the objective of the two greatest tacticians of the sailing period, Suffren and Nelson, was the concentration of forces; it must be remembered, however, that they attacked a part of the enemy's line, relying upon overcoming it before the remainder of the forces could come to its aid. This reliance was justified: (1) by the slowness of the movements of the sailing ship; (2) because the fighting could not be efficacious unless the vessels came broadside to broadside with those of the enemy. It resulted from this that *the forces not attacked were placed under conditions of non-offense for a time sufficient to secure decisive results.*

Naturally, the advisability of concentration is indisputable

to-day as in the past, when we have conditions of position analogous to those pointed out; or when the part of the enemy against which the offense is not directed is in a position of inability to offer offense; that is, when our own forces are in a sector of minimum offense of the enemy's alignment. The analogy also exists when a part of the enemy's force is so distant with respect to the remainder as to offer a sensibly less efficacious offense. In other words, the advisability of concentration is clear when, with respect to the enemy, we have an advantageous position.

Definitions.—When an alignment has not the advantage of being in a sector of minimum offense of the enemy, it may be said that, with respect to the said enemy, its positon is tactically advantageous, or equivalent, or disadvantageous, according as—supposing the enemy's offense to be concentrated in the best manner—it permits of executing the firing at distances less than, equal to, or greater than those at which the enemy fires.

With equivalent alignments it must be remembered that, in concentrating the offense, the ships at which we do not fire are in conditions of tranquility; and hence there exists the advisability of distributing the fire, because the offense offered is also a reciprocal-function of the offense received.

This last advisability cannot be considered when the distance exceeds a certain limit, which it seems should be placed at 8000 meters; in such case concentration becomes a necessity, to the end that the offense may be efficacious, and its results may quickly be tangible; and this, remembering that, as the distance increases, the probability of hitting rapidly diminishes.

Under such conditions it is then indispensable to prescribe that the ships of one and the same group (taking into account the limits pointed out in the preceding section) shall concentrate their fire upon one of the enemy's ships; this, however, does not imply the advisability of two groups of ships having for objects of concentration two hostile units forming part of the same group, when our own groups are not in a sensibly advantageous position with respect to the enemy's groups. Indeed, the convenience of distributing the fire must here be considered analogously to what has been set forth above; besides, the tactical necessity of dividing the ships into groups according to the standard of homogeneity is evident. So, then, having two units damaged in one of these groups, a combatant has his maneuver-

ing qualities reduced in that group only; while, if the damaged units form parts of two different groups, the maneuvering qualities of the whole fleet undergo a reduction notably greater.

In conclusion, we may formulate the following general criteria, the application of which is naturally subordinated to the necessity of not often changing the objective that it is sought to secure:

(1) At the maximum fighting distances it is necessary for the ships of each single group to concentrate their fire.

(2) When the distance is below a certain limit (8000 meters), it is best to distribute the fire, unless one has a sensible advantage of position, sufficient to render concentration advisable.

(3) In concentrating the fire from equivalent positions, the enemy's ships which are the object of concentration should preferably belong to different groups.

ELEMENTARY ALIGNMENTS.

15. *The Ship Upon Which to Concentrate.*—For the analysis of the advantages of position, let us refer, first of all, to the hypothesis of elementary alignments; or to simple, rectilinear alignments of a length not exceeding 2500 meters, necessary for six ships placed at intervals of 500 meters. At the present time this distance is to be considered as normal, by reason of the high speed and the dimensions of the battle units. From what has been noted in section 13, it is possible to concentrate the fire of all the ships of the alignment upon a single enemy's ship.

When not otherwise indicated it will be understood that the length of the adversary's alignment is supposed to be the same.

The natural target for each ship is evidently the nearest; or, it is that which is found at the foot of a perpendicular dropped from the ship upon the enemy's alignment. It follows from this that, except under special circumstances, the most opportune ship for the concentration of fire must be held to be the one that is nearest to the center of the projection of our alignment upon that of the enemy.

It is also necessary to take into account the importance of *continuity* in the concentration of the offense. From this results the advisability that the enemy's ship upon which the fire is concentrated should be at an extremity of the alignment; which,

in its turn, we shall see confirmed when we come to discuss the maneuvering.

We establish, then, that in general *the enemy's ship for concentration should be the extreme one which occupies the position nearest the center of the projection of our alignment; or, such ship is the extreme one on the side on which the inclination of the enemy's alignment is less than 90°.*

By this rule we may determine the ship for concentration, unless the inclination of the enemy's alignment to the line joining the centers is 90°. There may then arise two cases: (1) Our own alignment is also normal to the line joining the centers. (2) Our alignment is not inclined 90°.

In the first case it evidently makes no difference upon which extremity of the enemy's alignment we concentrate.*

In the second case, firing upon the extremity which is toward the point where the alignments converge, it is discovered that, with respect to the other extremity, the limits between which the firing distances are included are wider. Moreover, it may not always be possible to concentrate the offense upon the aforesaid extremity, which may be in a sector of minimum offense; while a certain advantage in fire control may result the more nearly we approximate to uniformity of distance. In any event, in the case to which we now have reference, the proper extremity is not precisely designated by the conditions of distance, and hence is selected on the basis of the objectives of the maneuvering.

16. *Inclination.*—It is easy to discover (see Fig. 6) that, to an alignment, A_1A_2, normal to the line joining its center C_A with the center C_N of the enemy's alignment, N_1N_2, we can oppose only an equivalent, or a disadvantageous alignment. In fact the party N may have an alignment normal to C_AC_N, and then the

*It is to be noted that if we were to concentrate the fire upon the enemy's center, rather than on an extremity, the firing distances would not be sensibly different. Calling r the distance between the centers, r_m the mean firing distance, for alignments 2500 meters long, we obtain the following:

VALUES OF r_m.

r	Firing on the center.	Firing on an extremity.
8000 meters	8045 meters	8200 meters
6000 meters	6065 meters	6250 meters

(Author's note.)

alignments are equivalent; or, it may assume an alignment differently inclined, as in the figure. In the latter case, from what has been said in the preceding section, the ship for the concentration of the A party is N_1; and that for N is A_1, it being supposed that the angle $N_1C_NC_A$ is not too small. Drawing from N_1 the perpendicular N_1P_A to A_1A_2, the firing distances for A are between P_AN_1 and A_2N_1; and those for N are between N_1A_1 and N_2A_1.

We have

$$N_1A_1 > P_AN_1.$$

The two triangles $N_2N_1A_1$ and $A_2N_1A_1$ have the side N_1A_1 in common; the sides N_2N_1 and A_2A_1 are equal; the angle

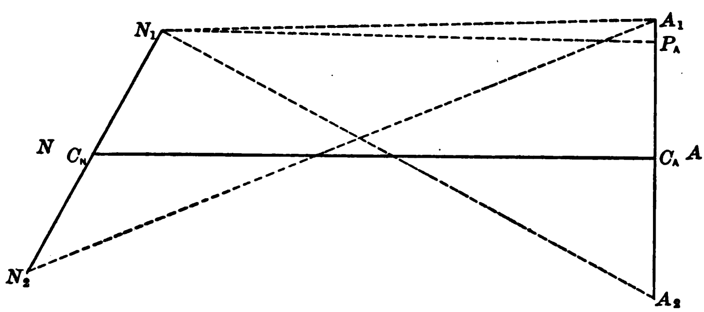


FIG. 6.

$N_2N_1A_1$ is obtuse, while $N_1A_1A_2$ is acute; hence

$$N_2A_1 > A_2N_1.$$

Analogously it is demonstrated that the firing distances of N are also greater than those of A when the firing is concentrated upon A_2.

The alignment of the party N is therefore a disadvantageous one, conformably to the proposition enunciated; from which we quickly draw the following deductions: (1) If the enemy's alignment is not normal to the line joining the centers, our assuming an alignment normal to the said joining line places us in an advantageous situation. (2) Of the two alignments, the situation of the one whose inclination to the line joining the centers is nearest to 90°, is the most advantageous. (3) With equal inclinations to the said joining line there is equivalence. It is worth while to note that, when this is realized, the angles that the lines

joining the corresponding vessels make with their directions are equal.

The inclination to the line joining the centers generally constitutes the best guide for estimating the advantages of position.

Definitions.—To the position of the alignment inclined to 90° to the line joining the centers we give the name of *fundamental tactical position.*

We say that an alignment *crosses the T* (or is in position to *T*) when it is in the enemy's sector of minimum offense.

For *crossing the T,* that inclination which permits having the minimum firing distances, would seem to be the best; in other words, in penetrating into the enemy's sector of minimum offense, it would be necessary to incline our alignment, at the extremity nearest that of the enemy, as far as the limit of his zone of maximum offense. Let us consider (Fig. 7) wherein $\beta = XA_1N_1 = YN_1A_2$ is the angle of which mention was made in section 13; this hows an alignment of A that crosses the T. The alignment N_1N_2 may still fire upon A_2, but A is in a momentary situation that is very advantageous, because its firing distances, putting $r = N_1A_2$, are practically included within the limits, r and $r-2000$; while for N, the distances are between the limits, r and $r+2000$.

But, in order to escape from this disadvantageous position, it is enough for the party N to rotate his alignment in a way which will permit him to fire upon A_1; in other words, in order that the positions may be equivalent, it is sufficient for the party N to rotate his alignment through the angle $N_2N_1N'_2 = A_2N_1A_1$; a greater rotation produces an advantage for N.

It is seen, then, how easy it is to eliminate the advantage of A when the T is crossed in the manner indicated; it is well, therefore, to seek to secure an advantage which, although smaller, may be maintained for a longer time. It is evident that the position of N will be so much the longer defective, the greater the amplitude of the rotation necessary to establish equivalence. It results from this that *the advantageous alignment for crossing the T is the fundamental one, A_2F.*

It is clear that, with alignments of different lengths, the shorter one is in a theoretically advantageous position, not only when, with respect to the enemy, it has an inclination nearer the fundamental one, but also, when it has an inclination equal to that of the enemy.

In the practical cases, the difference in length between two alignments that are not very different in strength cannot be very great. The difference in the number of ships may be one or two; and hence the difference in length may be 500 or 1000 meters; and since only a small part of it can affect the conditions of position, its influence appears to be negligible.

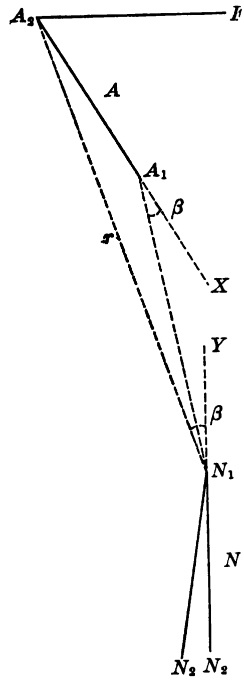


FIG. 7.

17. *Equidistant Positions.*—In this part of the subject, in studying the momentary situations—although without entering into an examination of the movements—it is necessary to keep in mind as a guide the practical object sought.

The deductions drawn in the preceding section have real practical importance, because they permit us to estimate whether it is better to change the alignment, and if so, how.

Except in special cases, even if two adversaries move, keeping their rectilinear alignments unchanged, evidently their inclination to the line joining their centers changes. Since a rectilinear alignment cannot be instantly changed, it appears necessary, as a complement to the deductions just mentioned, to seek for a form of alignment that closely approximates to the fundamental one, and that, with respect to the line joining the centers, can easily and continuously be maintained.

To this we come with the following observations:

(1) An elementary alignment in the arc of a circle having for its center an enemy's ship, may practically be considered as a rectilinear alignment normal to the line joining its center with the aforesaid enemy's ship.

(2) Two adjacent ships of an alignment may be said to be on the arc of a circle having an enemy's ship for a center, when, for each one, the straight lines joining them respectively with the friendly ship and with the hostile ship, form an angle of about 90°.

(3) It is well known that the simultaneous change of course of several ships must of necessity be successive at very short intervals of time; each ship having to wait for the movement to be begun by the ship next within, on the side toward which the change is made. From this it follows that, in the tactical steering of an elementary alignment, the extreme ships are to be considered as regulators; inasmuch as we can conceive that, while one of them completes the movements of the change of course in a wide sweep, the others may imitate them in a continuous manner, tending to maintain the parallelism of the courses. This being the case, on the basis of the two preceding observations, it appears advisable to consider what alignment is obtained *if every ship continually maneuvers with the criterion of considering itself in position when the angle between the line joining it with the*

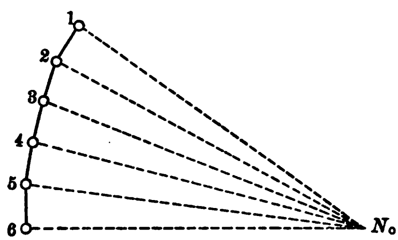


FIG. 8.

adjacent ship on the side toward the regulator, and that joining it with the enemy's ship of reference, is 90°.

The form of alignment is that indicated in Fig. 8; this form is a broken equilateral one, with the inclination of its sides to the radius vectors drawn from the pole N_0 (the enemy's ship) equal to 90°.

Distinguishing the units of the alignment by numbers from 1 to 6—No. 1 being the regulator ship—and indicating the respective distances from N_0 by $r_1, r_2, \ldots r_6$, we have

$$r_2^2 = r_1^2 - d^2,$$
$$r_3^2 = r_2^2 - d^2 = r_1^2 - 2d^2,$$
$$\ldots\ldots\ldots\ldots\ldots\ldots,$$
$$r_6^2 = r_1^2 - 5d^2.$$

With the customary value of $d = 500$ meters we obtain:

for $r_1 = 8000$ meters, $r_6 = 7920$ meters;
for $r_1 = 6000$ meters, $r_6 = 5900$ meters;
for $r_1 = 4000$ meters, $r_6 = 3840$ meters.

Within the limits of long-range battle—the difference $r_1 - r_6$ being thus absolutely negligible—the form of alignment that is obtained in the manner above indicated may in effect be held to be that on an arc of a circle, or at positions equidistant from N_0; and hence, by the first of the preceding observations, it constitutes a rectlinear alignment normal to the line joining its center with N_0.

Such a form of alignment satisfies the requisites above specified; in other words, if N_0 is the center of the enemy's alignment, and we suppose that our forces have the fundamental tactical position, this position thus appears to be susceptible of being maintained.

Reserving it to ourselves to discuss in its turn this question with regard to the maneuvering, we hold meanwhile that, in order continually to tend to the securing of the advantages of position pointed out in the preceding section, the alignment with equidistant positions with respect to the enemy's center will generally appear to be advisable.

It is readily seen that if our force is outside of the zone included between the perpendiculars to the enemy's alignment drawn from its extremities, a sufficiently advantageous form of alignment may be that with positions equidistant from the enemy's nearest extremity; and it is so much the better, the nearer the position of our center to the prolongation of the enemy's alignment.

18. *Composite Alignments.*—Two contiguous elementary alignments, one on the prolongation of the other, constitute a composite rectilinear alignment.

Two alignments of this kind opposed to each other, if of equal length and equally inclined to the line joining the centers, are in equivalent positions; because, from what has been said in sections 14 and 16, equivalence exists between the corresponding elementary alignments. It is readily seen that, for a given inclination to the enemy's alignment, the most advantageous position for our own alignment (if the condition is imposed that it be rectilinear) is the one normal to the line joining the centers; because in this way, the single rectilinear alignments are in positions nearest that of the fundamental position.

The condition mentioned (rectilinear alignment) is, however, neither necessary nor advisable. In regard to position, it is

advantageous (and it is intuitively seen that it may be desirable for elasticity of maneuvering) that each elementary alignment, while respecting the bond of compactness, be left free to incline itself in the most opportune manner. From this are derived *angular* alignments, like that of Fig. 9, in which one elementary alignment of A is normal to $C'_{A}C'_{N}$, and the other is normal to $C''_{A}C''_{N}$.

In practice, from what has been said concerning equidistant positions, the angular alignment may be composed of arcs of circles having their respective centers in convenient points of the enemy's line.

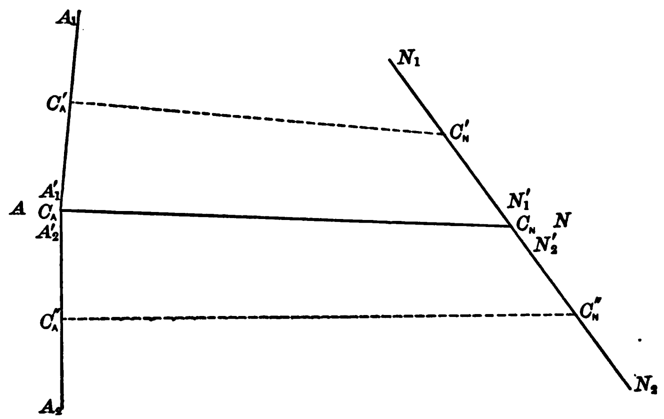


FIG. 9.

As has been noted in section 14, when the inclination of the enemy's alignment to $C_{A}C_{N}$ differs notably from 90°, the concentration of the offense of the two elementary alignments of A upon two ships of the same elementary alignment of the enemy is advisable; in such case the alignment of A becomes nearly the arc of a circle with its center in the middle of the said elementary alignment of the enemy.

On account of the disadvantage of position and the manifest difficulty of maneuvering which is encountered with alignments of great length, the hypothesis of greater lengths than those that are included in the two elementary alignments of six ships each, is logically to be excluded.

19. *Double Alignments.*—The number of ships that can maneuver in a single line being thus limited, in order to keep compact a force of greater size, it is necessary to have recourse to an align-

ment on two parallel lines, near to each other, so placing the ships in the line on the side away from the enemy, that they may fire through the intervals of the other line.

When the fleet is not very numerous, it seems logical to make use of such an expedient for reducing the length of the alignment.

It is observed, furthermore, that a group of antiquated ships, and ships deficient in protection, but yet having good speed, such as not to embarrass the tactical and strategical control of the fleet, may represent an element of offensive power that can usefully be employed against an enemy's armored fleet. In order to employ such ships, safeguarding them in order to prevent the enemy from bringing about their loss by means of a brief concentration of force, which would produce serious moral effects, one of two systems worthy of consideration is that of placing the said ships, so as to enable them to fire through the intervals of the other line. Thus we have a third case in which the double alignment may be of use.

Evidently, for such alignments, there exists the importance of the fundamental position; that is to say, there exist the principles deduced in the preceding section for simple alignments.

It is intuitively perceived, however, that, with this form of alignment, besides rendering it possible for the enemy to launch torpedoes from long distances with a certain possibility of hitting—as has been noted in the preceding chapter—we encounter other notable inconveniences with respect to a simple alignment.

(1) Diminution of the maneuvering qualities of the fleet; difficulty of taking up angular alignments.

(2) Increase of the amplitude of the sectors of minimum offense.

With the first of the inconveniences mentioned we shall occupy ourselves in Part II of our study. In order to estimate the second, we observe that, in order to fire in the intervals between the ships of the inner line, the limit of approach to the ships of the inner line by the ships of the outer line is naturally determined by the condition that the distance between ships shall not fall below the normal distance of 500 meters.

This being understood, let us determine the amplitude of the sectors of minimum offense of an elementary double alignment *abc, a'b'c'* (Fig. 10), composed of six ships in a manner analogous to that which was used in section 13 for a simple alignment.

Let us consider the triangle *aba′*, formed by two ships, *a* and *b*, of the inner line, and by *a′*, which fires through their interval. From what has been said in section 13, the position of *a′* is the limit position which permits offense in the direction of the alignment *cba* when there is realized

$$ba'a = \epsilon_1 + \epsilon_2,$$

where (45° forward of and abaft the beam being the amplitude of the sectors of maximum offense of the ships under considera-

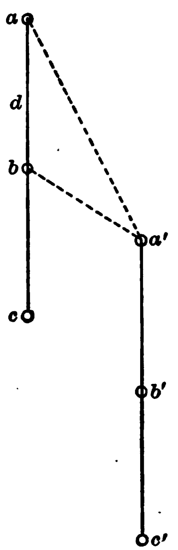
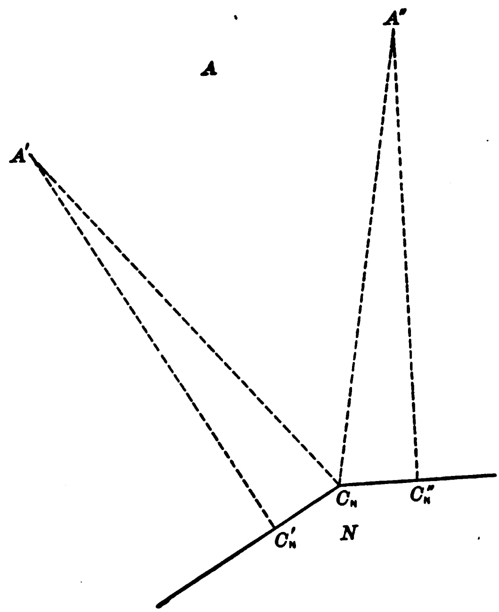


FIG. 10.



FIR. 11.

tion, and L the length of said ships) the angles ϵ_1 and ϵ_2 are deduced from the equations (section 13)

$$\sin \epsilon_1 = \frac{L}{ba'} \sin 45°,$$

$$\sin \epsilon_2 = \frac{L}{aa'} \sin 45°.$$

To the end that the offense may converge upon a single target, the value of *ba′a* must be somewhat greater than that above mentioned. It is found by trials that the limit position of *a′* (which determines those of *b′* and *c′*) may be held to be reached when

$ba' = a'c = d$; consequently, indicating by β (as in section 13) the half amplitude of the sector of minimum offense of the double alignment, we have $\beta = 60° - 15° = 45°$ (about), to be compared with the value $\beta = 20°$ obtained under the hypothesis of the simple alignment.

On account of the inconveniences pointed out, it seems logical to affirm that the double alignment is not to be adopted except in case of absolute necessity.

20. *Groups.*—We will now consider the hypothesis that the parties A and N, opposed to each other, are of the same strength and each formed by two elementary alignments, which, for the party A, are separated into the groups A' and A''; while N has his forces compact and on a simple alignment.

In Fig. 11 we indicate by A' and A'' the positions of the centers of the respective groups, the alignments of which we suppose to be in the fundamental positions with respect to the nearest elementary alignment of N.

If A' and A'' are at the same distance from C_N, the party N, by assuming an angular alignment with the sides respectively normal to $A'C'_N$ and $A''C''_N$, places itself in a position of tactical equivalence.

If A' and A'' are at sensibly different distances from C_N, the party N may assume an opportune alignment with respect to the nearest group and concentrate the offense on two of its ships; in this way the situation of N is advantageous. Moreover, when the angle $A'C_NA''$ exceeds 90°, it may befall that the party N can utilize the guns on both sides. It is therefore necessary to bear in mind that while in the sailing period the concentration had logically to be sought by placing the enemy between two fires, to-day the opposite is important. Naturally this consideration has no importance in case the party N is entirely made up of ships all of the principal guns of which have a field of fire on both sides.

In general it may be understood that the position of the compact fleet is so much the more advantageous the nearer it is to the line joining the groups (externally or internally).

From what has been said it results that, for the party having compact forces, we may assume conditions of equivalence and also of superiority, with respect to the other that is broken up into groups. Under the hypothesis considered, the advisability

of this last system is not excluded by this, but it is important to hold: (1) that such advisability is to be considered only in regard to the maneuvering; (2) that an echelon of groups in distance would be dangerous.

II. We will now consider the hypothesis that the forces opposing each other are equal, and that each party is so numerous that, in order to be compact, recourse must be had to the double alignment. In order to eliminate the inconveniences pointed out in the preceding section, it is possibly proper to prefer the separation of the forces into two divisions in simple alignment. In Part II we shall consider when the impossibility of doing so exists, or under what relative conditions of mobility maneuvering by groups may expose one to serious risks.

Setting aside the case in which the conditions just mentioned impose the double alignment, this may be advisable when the number of battleships at one's disposition is greater than that with which two groups may be formed in simple alignment; in fact it is well to note that *the greater the number of groups, the smaller is the probability that their movements may be co-ordinated;* and hence, in general, it seems advisable not to form more than two groups (exceptionally three), even at the cost of having recourse to the double alignment.

III. It is to be held as an axiom that, in general, it is not well to divide the fleet into groups of the same importance; rather than have two groups, both of them of small manageability, it is preferable to decide that one of them shall be endowed with special aptitude for the acquisition of advantageous positions. We reserve it to ourselves to develop, in its turn, this idea of the division of the forces into a *principal squadron* and a *flying squadron.*

Summing up, when fleets about equal in strength and not very numerous are opposed to each other, the breaking up into groups can only be advisable in order to obtain the maximum freedom of maneuvering; for numerous fleets, this expedient appears to be preferable to the double alignment. When the breaking up into groups is not rendered necessary simply by this numerical cause, the idea that prompts it may be that of attempting enveloping movements (crossing the *T*) by means of a flying squadron.

On the basis of the ideas advanced, the discussion of the hypothesis that both the adversaries are divided into groups is evidently simple.

In order that the battle may resolve itself into partial actions between single groups, this would have to be the purpose of both the adversaries. But, as it is logical to endeavor to concentrate the action of two groups upon a single enemy's group, the advantageous alignment (keeping in mind the relative definition of section 12) appears, in this case also, to be the fundamental one; while the echelon of groups in distance is disadvantageous unless the enemy adopts the same system.

21. *Natural Elements.*—In determining the advantages of position of two adversaries many elements enter into the account besides the situation of the respective alignments; as, for instance, the natural elements (sea, wind and sun), as well as the conditions of position with respect to the coast and to the strategic objectives.

Concerning the importance to be attributed to these elements it would be vain to pretend to formulate well-defined rules; it is clear that the values that may be given to them are to be subordinated to the necessity of having an opportune alignment in the respects already pointed out; and that holding it bound by too many conditions, signifies the creation of useless shackles. On this account we shall take only a rapid survey of the aforesaid elements.

With the sea greatly agitated, the difficulties of firing are very great; the combat may be reduced to a useless waste of ammunition, or, if there are decisive effects, the case itself may have much to do with them. Nevertheless, this does not mean that we are only to fight with a smooth sea; even with a rough sea an admiral will seek to oblige an enemy to fight if it is rendered necessary by the strategic situation; in which case, it is possibly well to avoid presenting the beam to the sea, diminishing in this way the difficulties of firing and the risk of receiving shots below the water-line. It must be remembered, however, that the gunners must be accustomed to firing under any conditions whatsoever. The situation of a fleet that, in order to obtain good fire control, would be obliged excessively to hamper the maneuvering would be a sad one.

With a fresh wind in the direction of the plane of fire it is doubtful whether it is better to fight with the lee side in action or with the weather side. In the first case, at high speeds, the smoke issuing from the funnels renders the firing difficult; in the second, the smoke and the powder gases are driven back into the

turrets and casemates, the occurrence of flarebacks is favored, and the lenses of the telescopic sights may be dulled by spray. Pros and cons also exist if we consider the direction of the wind with respect to the course of the ship. A wind that blows in the direction of the longitudinal axis envelops the range finders and the observers in the tops in smoke. If the wind comes from ahead, with a fleet in column of vessels, each ship is enveloped in the smoke of the preceding one. If the wind comes from astern, the smoke hangs over the ships a long time. It seems, then, that it may be advisable to maneuver without troubling oneself about the wind. Only a ship that has the defect of having guns but little elevated above the sea could have much interest in keeping to windward of the enemy.

The direction of the solar rays may have considerable importance when the sun is only a little above the horizon, because, notwithstanding the colored glasses on the telescopic sights, having to fire with the sun in one's eyes is a grave inconvenience. It is logical to seek to escape from this situation by rotating the line joining one with the adversary in a way that tends to bring the sun at one's back. When the sun's rays make a considerable angle with the plane of fire the aforesaid inconvenience is negligible.

It is well known that the target can better be seen when it is projected upon the horizon rather than upon a coast; it may then be desirable to be between the enemy and the coast, whenever, naturally, the neighborhood of the latter does not interfere with the liberty of maneuvering.

Finally, it is clear that the position of the adversaries considered with regard to strategic centers may be of importance; but this cannot justify long maneuvering out of range, which may cause the risk of losing an opportune occasion for fighting. The candid truth which history shows us is not always remembered, is that the issue of the war depends upon the battles.

CHAPTER IV.

THE FIGHTING DISTANCE.

22. *Uniformity of Distance.*—The problem which we propose for ourselves is that of establishing the criteria proper for determining the most convenient fighting distance, or the *distance of maximum utilization.*

First of all, it is well to discard two methods that may be attractive on account of their facility for furnishing a result; for this purpose let us refer to the simplest hypothesis, that is, of the naval duel.

(1) We might seek the solution by calculating the difference that exists between the two adversaries in the total energy developed by the projectiles on impact. The distance corresponding to the most advantageous value of the said difference would be the distance required. It is clear that such a method would be absurd, since there exists no equivalence of effects with equality of dynames * developed by the different kinds of guns. Aside from this, the method would evidently be one-sided.

(2) We might place the penetrating power of the guns of each combatant in comparison with the thickness of the enemy's armor. But, in this comparison, what shall we hold to be the inclination to the plane of fire? Let us suppose our ship to be at a distance r from the enemy, who is able to pierce the side armor, when the ship presents her beam, with a projectile that, at the above mentioned distance, has a residual velocity v. If, while remaining at the distance r our ship assumes the inclination ψ to the plane of fire (counted from the beam), from what has been said in section 4 (Chapter I), this is equivalent, from the defensive point of view, to being placed at the distance at which the residual velocity of the aforesaid projectile is $v \cos h\psi$ (where $h=1$); the offensive power, however, remains constant unless the direction ψ is outside of a sector of maximum offense. It is easy to prove that even a moderate value of ψ is equivalent to a material change of distance, which is all the greater the greater is the caliber. Hence, the inclination to the plane of fire cannot be overlooked. Wishing to apply the above-mentioned method, it would logically be necessary to suppose that the adversaries have each other bearing in directions of maximum utilization; then, however, no conclusive result could be reached with ships having large extensions of armor with thicknesses not below 150 millimeters.

In any event, the method which we are discussing would also be one-sided, because, while considering the defensive element (neglected in the foregoing) we should set aside most important elements, to which we will allude.

* Dyname = 1000 kilogrammeters. (Translator's note.)

Methods of the nature above mentioned, even if they could furnish results logically worthy of consideration in the case of two ships opposing each other, or of two groups composed of homogeneous ships, would not be applicable to the case of fleets composed of groups of ships of different types. In fact, these results would be very different for the various types, and then the legitimate consequence of such methods would be to make the various parts of the fleet fight as independent groups, echeloned at different distances from the enemy. So, then, aside from the possibility of always adopting the system of maneuvering by groups, we cannot admit the advisability of the echelon in distance for reasons discussed in section 20; on the contrary, we derive from it that the idea to be assumed as fundamental is that of *the necessity of having the various parts of our fleet fight under conditions of a uniform mean distance.*

In comparison with the system of the echelon, which might give to the tactical employment of the forces a rigidly prearranged form, the idea just enunciated appears the more rational inasmuch as, with it, we at once perceive the possibility of regulating the development of the tactical action.

In virtue of this idea, the question to be discussed appears complex; and it is proper to add that the complexity does not depend solely upon the heterogeneity of the different divisions of the fleet. Indeed, the variables of the problem do not reduce to the weapons and to the protection, but we must take into account strategic factors, and others of a moral and organic nature.

23. *The Strategic Situation and the Fighting Distance.*—The axiom with which we closed the preceding chapter must be recalled here: *The war is decided by means of decisive battles.* Ought we to draw from this the corollary that every tactical action must be pushed to a finish, or that, unless it is developed to the point of obtaining the destruction of the enemy's forces, it is unprofitable?

The question is prejudicial to the subject we have under discussion, since, if the reply is in the negative, on that basis it may sometimes be well for the fighting distance not to fall below a certain limit.

To overcome the enemy is the desire of all who fight, but in some cases a tactical victory may be a strategic defeat. Some particular examples are necessary in order not to be misunderstood.

During the first period of the recent war, up to the fall of Port Arthur, the Japanese had to consider that, while the whole of their force was engaged, the enemy, even after the destruction of the first squadron in the Pacific, would be able to send a second squadron from the Baltic. Italy, in case of a war with France, given the present relative conditions of the naval forces, might be found to have a superiority with respect to one fraction of the enemy; we shall, however, have to consider that, if in the victory our forces sustain such injuries as to remain for a long time paralyzed, ours would be a Pyrrhic victory, because the adversary, although having had one of his fractions annihilated, will have acquired liberty of action with the remainder.

On the other hand, at Tsushima, Japan found herself obliged to seek the annihilation of the enemy, because that signified the complete solution of the martime struggle. Italy against Austria would have to seek to end the struggle by one decisive battle, because, supposing that we have a total superiority of forces, every elimination of equal forces would be to our advantage. England, given the necessity of keeping open her commercial communications, and given also the development of her forces, would have to seek the destruction of the enemy. These examples demonstrate that the axiom which establishes that the object of fighting is to overcome the enemy, admits as a corollary, not the unconditional advisability of a decisive struggle, but *the necessity of pushing the fight as far toward a finish as is permitted by the strategic conditions.*

To establish firmly this postulate, it is necessary to examine the doubts that may be formulated on the basis of the principles of war on land and of naval history.

In the history of war on land it is set down as incontrovertible that the shock of grand masses should be of an exterminating character. To deny this would be to signify the return—as Clausewitz wrote: *—" To the systems of warfare that preceded the Revolution and the French Empire, in which there were manifested the falsest tendencies, pretending to aggrandize the military art the more war was deprived of the use of the only means proper to it: the annihilation of the enemy's forces." Such false tendencies consisted " in the pretension of the possibility, by directly seeking only a limited destruction of the forces

* Teoria della grande guerra. Vol. I.

of the enemy, of arriving, by way of wise combinations, at his complete direct enfeeblement; or, in other words, of exercising, by means of small blows ably administered, such an influence over his will as to lead him the more promptly to submit. . . . . The direct destruction of the armed forces of the enemy must stand before every other consideration."

We observe that in affirming the possibility of having, in naval battle, to consider also the stretegic situation, we have not denied the correctness of the axiom concerning annihilation; we have only expressed a reserve under the hypothesis that, after the hostile naval forces that we have confronting us, we must keep ourselves in condition to meet others of them, having at our disposal only our present forces; or under the other hypothesis that we have already confronting us the entire forces of the enemy, but we, on our part, have not a sufficient force to give us the probability of victory in a decisive battle; it may be a case of delaying the battle until the moment in which the enemy offers so vital an offense as to oblige us to stake all against all.

The comparison, then, must begin by being made with the situation of an army, A, which has confronting it a hostile army, B_1, about equal in strength; and which forsees having afterwards to fight also another army B_2. The question to be propounded is this: Does there exist for A the possibility of pushing the fight with B_1 to a finish, and of afterwards finding himself still in condition to oppose B_2? Evidently the reply may be in the affirmative; the annihilation of B_1 may bring great loss to A, which, no matter how great, may not be so important a fraction of the total as to produce incapacity to oppose B_2; the moral advantage acquired will be so great as largely to compensate for the said loss; and then, it will perhaps be possible to fill up the vacancies by drawing upon the great resources in men that modern states possess, given the national character of the wars.

At sea, under analogous conditions, the struggle against B_1—given the fact that it is victorious—*if it has been a fight to a finish,* will inevitably have caused serious losses which will either not be reparable, or will not be so in sufficient time; in other words, either we shall have lost ships, or we shall have them so seriously damaged as not to be able to count upon them when we have need of them.

The difference between the land and the sea depends essentially

upon the fact that on land it is a struggle of men; at sea it is a struggle of ships. On land, numbers constitute a great factor; at sea we have only a very limited number of units, and every elimination means the loss of an important fraction of the total.

On land, given the nature of the means, we are able to imagine only the fight to a finish or the barren struggle. The same was the case at sea during the sailing period—the condition of the means of war did not permit of efficacy except when fighting at close quarters. Under such conditions, the principle that the battle must be pushed to the annihilation of the enemy was a necessity; when the conservation of the forces was imposed, it was necessary to keep them in a potential state, just as, on land, in an analogous case, there was imposed the necessity of taking a flank position. Great admirals are not wanting to give us examples of this—it will suffice to cite some typical cases.

In 1673, Ruyter maintains himself in a state of efficiency behind the banks of Schöneveldt, because his fleet is inferior to that of the Anglo-French; in this way he conserves his forces until the time when Holland is threatened with invasion. In the war of 1778, Howe, owing to the inferiority of his forces with respect to those of d'Estaing, upon news of the arrival of the latter on the American coast, leaves the Delaware in order not to be obliged to fight under unfavorable conditions, and goes to take part in the defense of New York, in a position where the enemy does not dare to attack him. And when d'Estaing goes to support the troops of Washington in the attack on Newport, Howe goes promptly in advance to Rhode Island where, on account of the prevailing winds, he reckons upon keeping to windward, or launching fire ships if the enemy remains in the bay. The presence of Howe puts d'Estaing in a critical position, and therefore the French squadron profits by a favorable wind to leave the anchorage, thus abandoning Washington to himself. As Mahan observes, "the weaker fleet has fully beaten the stronger by virtue of its maneuvers."

To-day, the fact to be borne in mind is that long-range battle has acquired greater efficacy than in the past; and from this it follows that by keeping the development of the action within certain limits, it may be profitable to engage tactically, not only in situations analogous to those in which battle was advisable during the sailing period, but also, in part, in others in which it

was then necessary to remain in a state of efficiency. It must, then, be acknowledged that, the conduct of the forces being inspired by the postulate which we support, as against the other which expresses the necessity of engaging only under conditions of being able to seek the destruction of the enemy, we shall have an increase and not a diminution of the *offensive spirit.*

We proceed, then, to seek the solution of the proposed problem on the basis of the idea that *the strategic situation may limit the development of the tactical action, as long as we have more interest than the enemy in the conservation of the forces; while under the contrary hypothesis, it is important to press the fight to its decisive phase; which naturally does not signify that it is well to close the distance from the beginning.*

24. *Tactical Zones.*—If the problem could be solved with methods of the kind mentioned in section 22—that is, on the basis of numerical calculations—it might be possible to give to the distance of maximum utilization a strictly determined value. But the variables to be considered are such that we are not able to reach a really logical result except by dividing the tactical field into zones of considerable width, and examining, with respect to the zones, the benefits that the two opposed parties can derive from the action. At the present time the subdivision that seems reasonable is the following:

1st zone, distances from 10,000 to 8000 meters (extreme range).
2d zone, distances from 8,000 to 5000 meters (long range).
3d zone, distances from 5,000 to 3500 meters (medium range).
4th zone, distances from 3,500 to 2000 meters (close range).
5th zone, distances less than 2000 meters (close quarters).

The heavy-caliber gun is the weapon of the first two zones; therein the medium guns are of use for the improvement of the firing and for action against unprotected parts; beginning at the upper limit of the second zone these guns begin to give notably good results. In the third zone the probability of hitting with the medium guns is sufficient for assigning a special value to their action. In the fourth zone, from what has been said in Chapter II, the employment of the torpedo is possible. In the fifth zone it is also necessary to take into account the possibility of collision; its limit being assigned according to a criterion of which we shall speak in Part II.

25. *The Initial Advantage.*—A first datum concerning the relative importance to be attributed to the different zones is found

in the following axiom: It is of the highest importance to obtain an initial advantage, because it has a compound influence; that is, it tends to increase the advantage, not only by reason of the material injuries which diminish the enemy's offensive capacity, but also because it produces moral injury and disorder.* In virtue of this, as has already been realized in the Russo-Japanese war, there may be felt by the winner a relative safety which is surprising.

The initial advantage may profitably be sought, especially in the first two tactical zones, because in them full allowance may be made for exercising control over the fleet; while the further we advance into the successive zones, the more we are under the sway of the unforeseen which reigns supreme at close quarters. In other words, *it is to be held that a struggle at extreme or at long range constitutes an efficacious means of preparation for the struggle at medium or at close range.*

On the basis of the principle thus established, we may be induced to seek battle in the zones within the second by an initial disadvantage, experienced or anticipated. Let us fix the ideas in this connection.

The shorter the distance, the greater is the percentage of effective hits for both the adversaries; but may this variation be considered the same for both? Evidently, no; the difference depends upon individual ability, upon the means at one's disposal, and upon the fire control.

The difference dependent upon the gun laying varies with the firing distance; in fact, at short distances, even a mediocre gun layer fires well; the difference in ability between two gun layers always makes itself the more felt as the distance increases, and when the ship is subjected to rolling movements. So, also, the

* "D'un côté, le commandement, désepérant du succès, tombera dans l'hésitation; il songera à sauver les débris de sa fortune; la direction deviendra incertain; l'artillerie, précipitant son tir pour rattraper l'avantage, gâchera ses munitions; les officiers seront impuissants à diriger leurs hommes.

"De l'autre côté, le spectacle sera tout différent au début de l'action, le courage n'est soutenu que par une effort de la volonté qui enlève à chacun une partie de ses facultés; mais aussitôt qu'on éprouve l'impression que l'ennemi commence à céder, une détente se produit; la confiance succède à l'apprehension. Chacun reprend son sangfroid; le combat devient plus méthodique. . . . . Dès lors la victoire est assurée."—Daveluy.

greater the distance, the more the ability of the directors of the firing affects the results.

With equal ability of the personnel, the better are our range tables, the greater the homogeneity of the armaments of our ships, and the better the state of our weapons, so much the more may we have confidence in being able to adjust the firing before the enemy can do so, or, to secure the initial advantage.

But, a priori, the elements just pointed out are almost entirely imponderable; the above-mentioned differences will have effective influence, but they cannot be estimated beforehand. Generally, then, at the beginning of the combat, each of the adversaries will be confident of securing the initial advantage; consequently, *if the one who can impose the distance* (in the manner which we shall consider in Part II) *has greater interest than his adversary in the conservation of the forces* (section 23), *the action will be limited to this phase; otherwise, it will consist of successive phases; but a phase in the first two zones is logically to be predicted,* except in the cases which we will now point out.

The arguments that can be deduced for maintaining that, without initial disadvantage, battle in the third and fourth zones may be expedient from the beginning, are the following:

(1) Inability to perforate the enemy's armor in the first two zones.

(2) The short life of the heavy guns.

It is to be observed that in the recent war the possibility of obtaining important tactical results, even without the effects of perforation, may have been demonstrated.

The importance of the initial advantage being admitted, given the fact that fighting at long range may serve a very useful purpose in preparing for the struggle at shorter distances, should we renounce it on account of the wear and tear to the heavy guns derived therefrom? Given the fact that we are disposed to risk the ships by closing the distance, why not also risk the guns in battle in the first two zones? The arguments adduced must be considered, but not by one of the adversaries alone; we ought not to preoccupy ourselves too much with the wear and tear of the guns, because those of the enemy are worn out equally with ours. It results from this that, while, on the one hand, in the first encounter we fight at long range, closing in afterwards according to circumstances, on the other hand, in continuing the war, we might be obliged to fight initially at medium range.

It is well, however, to hold that, having more interest than the enemy in the conservation of the forces, in order to be truly free to choose the tactical zone it is necessary that the choice be permitted by *the state of the ammunition supply and the number of guns in reserve,* which must at least be equal to that of the enemy; an inferiority in this respect evidently may render it necessary to seek to delay the battle until the strategic situation imposes a fight to a finish.

At this point in the discussion, in order to assemble the ideas concerning the interest that a belligerent may have in fighting in one zone rather than in another, let us consider the problem by parts; examining the influence of differences in the means of offense, and that of differences in the means of defense.

26. *Differences in the Means of Offense.*—Let us suppose that there exists between the adversaries a difference in the number, but equality in the kind of weapons.

If, with two opposed parties, A and B (ships or fleets), the first has over the second the advantage of n guns of a certain caliber, with equality in other conditions, the damage inflicted upon B is roughly equal to that sustained by A, increased by that which is produced by the n guns in advantage. Hence it is clear that *the difference in the number of weapons, with equality in the kinds of the same, makes its effect the more felt the more the distance diminishes;* and for this reason, unless an inferiority is so notable as to make it advisable to seek battle at close quarters, it produces an interest in fighting at long range and seeking to compensate for the disadvantage with dexterity.

Let us now suppose that A and B have guns of two kinds; for example, A has n_1 guns of heavy caliber more than B, while B has n_2 guns of medium caliber more than A. Diminishing the distance increases the efficiency of n_1 and n_2 alike; A, however, is interested in not allowing the distance to fall below the inferior limit of the zone in which the action of the heavy caliber is particularly efficacious; hence, for A, the second zone is suitable, while for B, the fourth zone is best, or the lower limit of the third, when it is desired to exclude the use of the torpedo.

In relation to the criteria just enunciated, the following observations are to be made:

(1) A ship, the guns of which are not capable of yielding the same return as those of the enemy (with equality in number and

in kind) on account of the minor dexterity of the personnel, may seem comparable to a ship less strongly armed; then, by applying the preceding criteria, this ship should be interested in fighting at long range, which would evidently be absurd. But the error lies in the comparison made; in fact, logically, the conditions of the said ship are to be compared with those of a hypothetical ship, the guns of which increase in number as the distance diminishes.

(2) Analogously to what has been said under the hypothesis of a superiority constituted exclusively by medium guns, in order to utilize to the maximum degree a superiority in heavy and medium guns, battle in the third and fourth zones would seem to be advisable. However, the importance of the initial advantage is to be taken into account, and the expediency of avoiding, as far as possible, having the superiority compromised by lucky shots. Consequently, at the beginning, long-range combat is preferable, passing afterwards to medium range, and finally to close range, in order to give the *coup de grace*. The combatant that gets the worst of it in the artillery battle, if he has not the possibility of imposing a fight at close quarters, will decide to launch torpedoes at long range. For the adversary, that might be the opportune moment for diminishing the distance and launching torpedoes without too many risks and with greater probability of success.

27. *Differences in the Means of Defense.*—On the basis of what we have noted in section 4 (Chapter I), a good distribution of 150 millimeters armor constitutes the *minimum* sufficient and necessary for the struggle at extreme range and at long range against ships armed with guns of heavy caliber. Aptitude for battle at shorter distances requires a thickness greater than the said limit, at least in the water-line belt. These criteria seem sufficient for estimating the influence that the relative conditons of protection of the adversaries may exercise upon the choice of the distance.

Ships with but little protection, but with great offensive power, may be employed against the secondary (unarmored) forces of the enemy, and also—if deemed necessary—against the principal forces, taking care to safeguard them in the manner indicated in Chapter III; in which case, however, the choice of the opportune tactical zone for the whole fleet is made independently of the presence of such ships.

Aside from this hypothesis, ships with little or no protection should avoid battle with strongly protected ships; but, when obliged to fight, they should seek to come to close range.

28. *Conclusions.*—On the basis of the preceding analysis, let us sum up for each tactical zone the conditions under which it may opportunely be selected.

Zone I is suitable for the search after the initial advantage, for the combatant that, by reason of the strategic situation, can least afford to risk his forces. It requires great organic preparation of the personnel and of the material. It is generally not capable of producing decisive effects, but is capable of accentuating differences.

To the one who desires to push the fight to its decisive phase, this zone would not be suitable when he cannot count upon a sufficient number of hours of daylight.

Battle in this zone is not possible except under the best weather conditions.

Zone II.—The combatant in the strategic situation above mentioned will pass to this zone after obtaining an initial advantage in the first zone, unless, having a greater number of heavy guns, he elects to develop the entire action in the latter. It will be the one in which, generally, the initial advantage will be sought by the combatant who desires the battle to take place in its various degrees of intensity. It is capable of decisive effects. Generally, both the adversaries will agree in desiring a prolonged phase in this zone.

Zone III is suitable for the one who obtains the advantage in the preceding zone, or who has an important superiority in medium-caliber guns, or heavy-caliber guns in bad condition.

Zone IV is generally suitable for giving the *coup de grace,* or when one has superiority in torpedo armament, or when one has ships more heavily armored than those of the enemy.

Zone V is not suitable for the one who has obtained advantage in the preceding zones. Whoever may wish to attempt a desperate stroke in order to re-establish his chances in the fight, will seek to enter this zone.

PART II.

MANEUVERING.

CHAPTER I.

Ideas on Naval Kinematics.

29. *Preliminaries.*—The motive that induces us to cite a few fundamental ideas on naval kinematics must not be sought for in a desire for mathematical divagations, nor for the study of battle maneuvers on the basis of aprioristic hypotheses concerning the movements of the enemy. The object that we propose for ourselves is that of determining criteria of the maximum simplicity, holding it to be an axiom that, in offensive contact, it is absurd to place confidence in tables, diagrams, or instruments for geometrical constructions. Furthermore, it is well to give notice that, while not excluding such means in contact out of range, and during exercises (and in the latter only until a sufficient habit in maneuvering is acquired), the only one of them that we deem indispensable for the conning of a ship under the fire of the enemy, is that composed of a horizontal disc upon which are marked the sectors of offense of the weapons, and in the center of which is a revolving alidade furnished with a sight vane.

But precisely in order to be free from all shackles, clearness of ideas is necessary concerning the solution of the principal problems of kinematics, and toward this we shall tend, limiting ourselves to the purely indispensable.

To fix the idea, let us refer to the case of two ships opposed to each other, observing that, on the basis of the deductions of Chapters I and IV of Part I, we cannot confine ourselves to considering the rectilinear tracks.

Indeed, in long-range battle, if we suppose that our ship is in the proper tactical zone, that the enemy bears approximately in a direction of maximum utilization, and that we maintain a constant course, after a short time—except in very particular cases—the inclination to the plane of fire could not be held to

answer to the tactical necessities; and hence it will be necessary to follow a new course.

In general, rather than change the course at intervals, and so disturb the fire control, there naturally comes the idea of satisfying the tactical necessities continuously rather than intermittently, by keeping the polar bearing of the enemy constant *for a certain time,* which can easily be done by means of the alidade of the instrument just mentioned. In this way, the track passed over is generally curvilinear; and its curvature is naturally a function of the enemy's track. As—steering thus by means of the sight vane—the ship continually changes her course, the doubt may arise that the disturbance of the firing may be continuous; we establish, then, the idea of taking also into consideration these curvilinear tracks, unless upon examination their radii of curvature prove to be very great. It is clear that if such conditions are realized, they present a real advantage by substituting continuous, but very slow, changes of course for those of notable amplitude between the successive courses of a broken right line.

Setting aside the effect upon the firing, it is intuitively seen that steering on a constant bearing may be advisable under some circumstances, because it permits the maximum simplicity of maneuvering that can conveniently be adapted in a continuous manner to the maneuvering of the enemy.

When the advisability of the continuous adaptation just now mentioned does not exist, and the problem is that of taking, with the greatest rapidity, a determined position with respect to a ship or a fleet of ships, the necessity of rectilinear tracks is evident. In fact, they permit of attaining the desired object in the minimum time, unless a curvilinear track may be convenient in order to diminish the uncertainties of the maneuver, and may permit of reaching the desired position in a space of time only slightly greater than the minimum.

In general, then, we may establish the necessity of rectilinear tracks:

(a) In contact out of range.

(b) In the maneuver of approach of a light, swift vessel.

(c) In the movements of friendly ships (evolutionary problems).

Bearing in mind what has previously been said, for the study of the movements of two ships—which forms the object of this

chapter—we are to consider rectilinear movements and those on a constant bearing.

30. *Indicator of Movement* (Fig. 12).—Let us consider the simultaneous positions of two ships, A and B, of which V_A and V_B are the respective speeds, and AA_1 and BB_1, the courses. If A_1 and B_1 are the simultaneous positions of said ships after an infinitesimal time dt, let us take A_1A_1' parallel and equal to BB_1, but in a contrary direction. The distance $A_1'B$ is equal to that of A_1B_1; moreover, the joining lines A_1B_1 and $A_1'B$ form the same angles with the courses of B and A. The geometrical locus of the points A_1' (of which A is the origin) is the trajectory or indicator of the relative movement of A with respect to B, called,

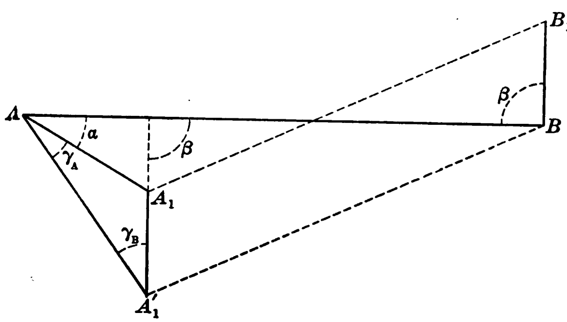


FIG. 12.

briefly, the *indicator of movement;* or, in other words, it is the track that the ship A, at a speed which is the resultant of V_A and V (the relative speed), passes over with respect to the ship B. which is supposed to be stationary.

31. *Generalities Concerning Rectilinear Movements* (Fig. 12). —If the tracks of A and B are rectilinear and the speeds V_A and V_B are constant, the indicator of movement will be rectilinear. In fact, from what has been said, the points of A_1' are aligned with A, the resultant of the speeds being also constant.

Consequently, if A must determine the proper course for bringing itself into a given position with respect to B, it is well to observe that the course that corresponds to the hypothesis of an immovable B is the indicator of movement; the problem is then reduced to that of passing from the indicator of movement to the course of A.

If we imagine a circumference described with its center at A and with any radius AA_1 which we take as a unit of measure, the course sought is obtained by joining A with the point A_1 of said circumference, the parallel from which point to the course of B cuts the indicator in a point, A_1', such that we may have *

$$\frac{A_1A_1'}{AA_1} = \frac{V_B}{V_A}.$$

If α and β are simultaneous polar bearings of A and B respectively (counted from the bow), indicating the relative speed by V_r, from the triangle AA_1A_1' we have

$$V_r = V_A\sqrt{1+\left(\frac{V_B}{V_A}\right)^2 + 2\frac{V_B}{V_A}\cos(\alpha \pm \beta)},$$

wherein it is necessary to use for β the positive or the negative sign, according as the two ships move toward the same side or toward opposite sides of the line joining them. The minimum value of V_r is $V_A - V_B$, which corresponds to parallel courses in the same direction.

If s is the segment of the indicator included between the points corresponding to the initial position and the final position, the time t necessary for completing the movement is

$$t = \frac{s}{V_r}. \tag{1}$$

Furthermore, indicating the angles formed by the courses of A and B with the indicator of movement by y_A and y_B respectively, from the aforesaid triangle AA_1A_1' we obtain

$$\sin y_A = \frac{V_B}{V_A}\sin y_B. \tag{2}$$

Since it must be that $\sin y_A \leqq 1$, there results from this relation: 1st, that any change of position of a ship, A, with respect to another, B, which is steering a fixed course, is possible when $V_A > V_B$; 2d, that if A has not superior speed, there are possible only those changes of position for which $\sin y_B \leqq \frac{V_A}{V_B}$; 3d, for a value of y_B, two supplementary values of y_A satisfy the above-

* Marking off from A a segment $\frac{V_B}{V_A}$, parallel to the course of B and in the same direction as V_B, and drawing from its extremity the parallel to the indicator of movement, the point A_1 is determined by the intersection of this parallel with the circle of center A and radius 1. (Author's note.)

mentioned relation. It is easily seen, concerning the aforesaid geometrical construction, that when $V_A = V_B$, a relative speed, O, corresponds to one of the said values of y_A; if $V_A < V_B$, the relative speeds corresponding to the two values of y_A are made in the same direction; and this must be taken into account in order to select the proper value of y_A, since both the values of y_A bring one to the desired position, but in different times; finally, if $V_A > V$, the two values of the relative speed have contrary signs.

32. *Chase Problems.*—The simplest application of the preceding deductions consists in ***determining the proper course for overtaking another ship.***

In this case, the indicator of movement is the joining line AB; therefore, during the movement, the two ships keep each other on the same polar bearings. The course sought can be determined with the geometrical construction, already mentioned, which it is superfluous to recall as it is practically done with an instrument having two alidades. The immediate determination of the proper course would require exact knowledge of the course and speed of the other ship; this not being presumable, recourse must be had to successive rectifications.

When there is no instrument available except one with a single alidade—mentioned in Section 29—the course to be steered must be estimated by eye and afterwards corrected until the polar bearing remains constant. In this way the ship A which gives chase generally follows a broken rectilinear track; we shall presently see how the rectifications just mentioned may be limited.

Conformably to observation 3 of the preceding section, the condition that the course steered should keep the polar bearing constant is necessary, but it is not sufficient to bring about a meeting; in fact, this may be verified for two courses of A which form supplementary angles with AB. When $V_A < V_B$ the meeting is not possible if B holds A on a polar bearing, from the bow, greater than that of which the sine is $\frac{V_A}{V_B}$. Both the above-mentioned courses may lead to a meeting, but naturally the one which makes the greater angle with the said joining line *cannot secure the object in the shorter time;* and the existence of such a solution is worth remembering in practice in order to avoid errors. In the case of $V_A = V_B$, the course that makes the greater angle with the joining

line and keeps the polar bearing constant, is parallel to the course of B; or, geometrically, it would lead to a meeting in an infinite time. Finally, when $V_A > V$, the course of A, which makes the greater angle, diverges from the course of B, and the ships may be considered as departing simultaneously from the point of intersection of the courses.

This being said, we observe that if A steers on a constant polar bearing equal or nearly equal to the one necessary for reaching a meeting in the shortest time, the indicator of movement is rectilinear, or it is very nearly a straight line; and hence A arrives at the meeting in the minimum time, or in a time slightly greater. It is unnecessary, then, to establish the precise condition that the

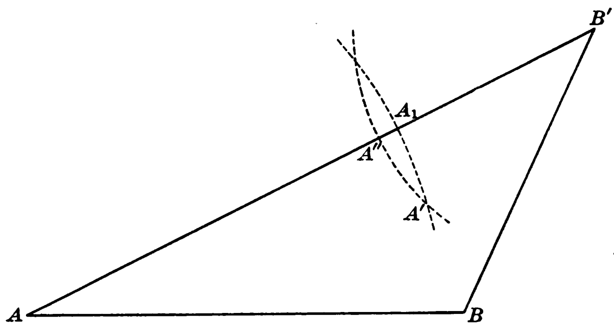


FIG. 13.

track of A be rectilinear; and this suggests the practical rule of not troubling oneself too much about the aforesaid rectifications of the course, *but determining an approximate course, and then steering so as to keep constant the polar bearing thus obtained.*

II. The problem just discussed is a particular case of the following: *To determine the course that a ship, A, must steer, with* a speed V_A, *in order to arrive, in the minimum time, from a distance R to a distance r from a ship, B, which steers a rectilinear course at a speed* V_B; *in case this is impossible, to determine the direction in which A must move in order to reach the minimum distance from B.*

In order to solve this problem, let us first of all demonstrate that if A' and B' are the positions of A and B when A has reached the distance r from B in the minimum time, the three points A,

A' and B' are in a straight line. This may easily be demonstrated by an absurdity.

Let us suppose $R>r$. Let us also suppose that A' is not upon the joining line AB' (Fig. 13) and that A_1 is the point of intersection of AB' with the circumference whose center is at A and whose radius is AA'.

Let A'' be the point of intersection of AB' with the circumference whose center is at B' and whose radius is $B'A'=r$. It is clear that AA'' is less than AA_1; if, then, the ship A had followed the course AB' it would have arrived at a distance from B less than r, in a time equal to that occupied in passing over AA'. Into such absurdity one always falls, except in the case in which A' is on the joining line AB'; the alignment mentioned is therefore necessary. The proposition enunciated is analogously demonstrated if $R<r$; that is to say, if, instead of diminishing the distance, A must increase it. From this it follows that when A arrives at a distance r from B, if this is accomplished in the minimum time, B must be found exactly ahead of him if $r<R$, or exactly astern of him if $r>R$.

If the ship A, which sees B pass ahead of it at the distance r, should continue on its course, it would evidently cross the track of B after a time $\frac{r}{V_A}$, in which time B would have passed over a space $r\,\frac{V_B}{V_A}$. It follows from this that, in order to execute the maneuver of approach from any distance, R, to a distance r, in the minimum time, it is not necessary to steer as if one wished to reach the ship, as was pointed out in Problem I, but *to maneuver in order to reach an imaginary point which is situated astern of B at the distance* $r\,\frac{V_B}{V_A}$, *and which moves with the speed and on the course of B.*

Evidently, the greater the distance r, and the smaller the advantage in speed that A has over B, the more important it is to bear in mind the difference between the exact solution—which results from the consideration just alluded to—and the approximate solution which corresponds to the hypothesis $r=0$, or to the other hypothesis $\frac{V_B}{V_A}=0$.

In contact out of range, in which there is a possibility of making a geometrical construction, the course sought is determined by laying off AB (Fig. 14), which may represent R, then taking a segment, $BH = r\frac{V_B}{V_A}$, in a direction parallel and opposite to the course of B, and finally forming (Section 31) the triangle AA_1A_1', in which A_1A_1' is parallel to BH, and wherein the ratio between the sides AA_1 and A_1A_1' is $\frac{V_A}{V_B}$. The solution may be obtained more simply by describing the arc of a circle with its center at B and with a radius r, cutting AH at a point H'; which indicates the course $H'B$ that A must follow, and in regard to which the general discussion of Section 31 is recalled to mind.

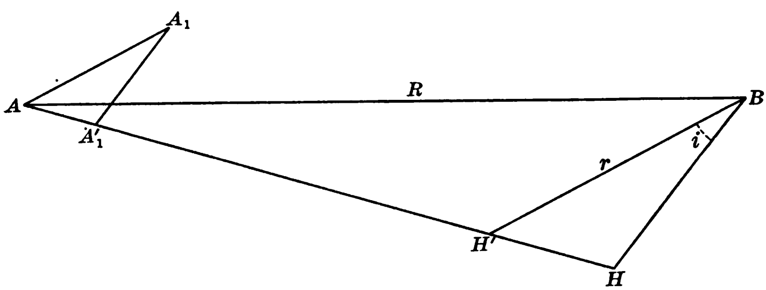


FIG. 14.

When A and B are in sight of each other the reason for applying the approximate solution in the manner indicated under Problem I, is that one cannot steer by sight vane for the point H, because that point is not distinguishable. Nevertheless it does not seem that the exact solution may be completely neglected, since we are able to come near to it, without any complication, by observing the following rule: *Maneuver initially as if it were desired to come to a meeting with B, and then, successively, at intervals, bring the sight vane by which we are steering toward B, more toward the bow, in such fashion that the said ship may be bearing ahead when the desired distance is reached.*

If $V_A < V_B$, so much the more necessary is it to refer to the general problem, inasmuch as the problem of meeting may be an impossible one; but we may approach to the minimum distance therefrom, which, as is seen in Fig. 14, is evidently that for which $H'B$ (and hence the course of A) is perpendicular to the indi-

cator of movement. In order to reach this minimum distance, the cosine of the angle i between the courses must equal $\frac{V_A}{V_B}$.

In contact out of range it is possible that it may be foreseen that the enemy will follow a broken rectilinear track when in the vicinity of the coast.

If the track of B (Fig. 15) is BB_1X, two cases may present themselves: 1st, A may arrive at the desired distance r from B, before B arrives at B_1; and then the solution is the one already

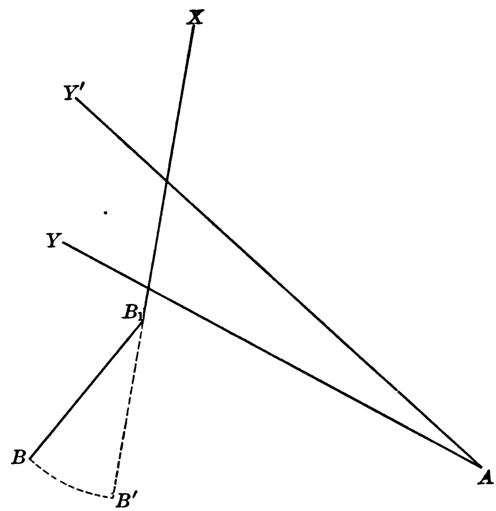


FIG. 15.

indicated. 2d, the course AY, along which A would have to move under the preceding hypothesis, intersects BB_1X in some point of B_1X. From B_1, then, we lay off on the prolongation of B_1X the segment $B_1B' = B_1B$. It is evident that the direction AY', in which A must move in order to solve the problem, is obtained by supposing that the movement of B always takes place along B_1X, and that B' is the initial position of B. Clearly, this course of reasoning might be extended to the case in which the broken rectilinear track has more than two segments.

When $r > R$, the solution of the problem enunciated is obtained in a way analogous to that required for $r < R$, observing that the course on which A reaches the distance r in the shortest time,

cuts the line of the course of B ahead of that ship, and at a distance $r\frac{V_B}{V_A}$; hence, unless A is exactly astern of B, the most opportune course for increasing the distance up to a certain limit as rapidly as possible, must be a diverging one.

33. *Evolutionary Problems.*—I. Let us suppose that B (Fig. 16) follows the course BX at a constant speed. If A finds itself,

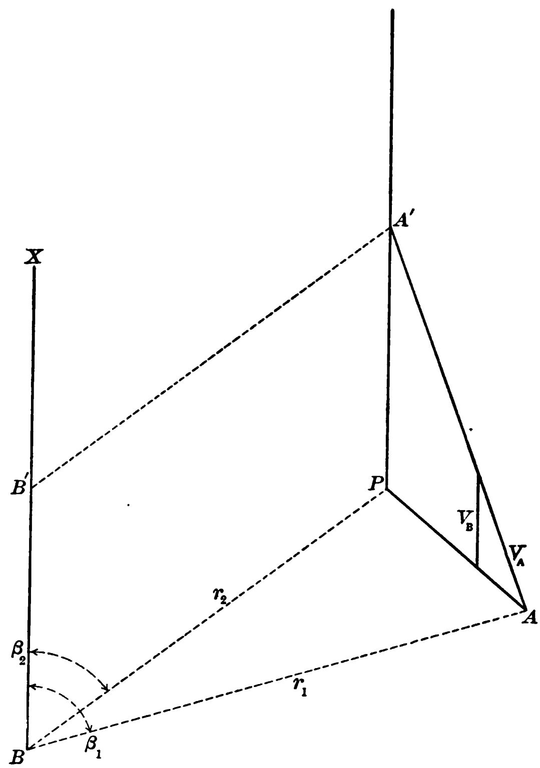


FIG. 16.

with respect to that ship, at a distance r_1 and on the polar bearing β_1, and desires to pass in the minimum time to the distance r_2 and to the polar bearing β_2—that is to say, to a position P with respect to B, which is supposed to be stationary—the line AP is the indicator of movement; and hence, with reference to it—as has been set forth in Section 31—setting aside the displacements due to changes of course, we may determine the course AA' that A must follow, and the necessary time.

The problem thus set forth is the one that presents itself when we aim at transporting ourselves from contact out of range, not only to a certain distance from the enemy, but also to a determined relative position.*

Moreover, what has just been said includes generically the cases realized in evolutions that are not performed in succession. If $\beta_1=\beta_2$, AB is the indicator of movement, and the evolution reduces itself to a change of distance; if $r_1=r_2$, the evolution consists of a change of bearing; the indicator of movement is then normal to the bisector of the angle PBA; that is to say,

$$PAB=90°-\frac{\omega}{2},$$

ω being equal to $\beta_1-\beta_2$.

II. Let us now consider the changes of bearing.

The perpendicular segment dropped from B upon AP—that is to say, $AB\cos\frac{\omega}{2}$—indicates the minimum distance at which the ships will pass during the evolution; it is generally held that the distance ought not to fall below 7/10 of the normal distance, which establishes for ω the limit of 90°.

It is easy to find the formula which permits of obtaining the angle δ through which A must change course, supposing, naturally, that in the position A, the said ship has a course parallel to that of B. From the figure we get

$$\delta=180°-\beta_1-PAB-y_A,$$

in which

$$PAB=90°-\frac{\omega}{2},$$

and y_A is given by equation (2) of Section 31; that is,

$$y_A=\text{arc sin}\left(\frac{V_B}{V_A}\sin y_B\right).$$

Then, since

$$\sin y_B=\sin(180°-\beta_1-PAB)=\cos\left(\beta_1-\frac{\omega}{2}\right),$$

we obtain

$$\delta=90°+\frac{\omega}{2}-\beta_1-\text{arc sin}\left[\frac{V_B}{V_A}\cos\left(\beta_1-\frac{\omega}{2}\right)\right]. \qquad (3)$$

* If the movement of B, instead of being on a single course, can be predicted to follow a broken rectilinear track, the method to be followed is evidently analogous to that indicated in the preceding section. (Author's note.)

The change of course must be made toward B, or in the opposite direction, according as δ is positive or negative.

In order to be able to pick out the value of δ from a table, the latter might be one with two entries (that is, $\beta_1 - \frac{\omega}{2}$ and the ratio of the speeds).

In order to eliminate the use of tables, recourse should be had to diagrams,* to an instrument with an alidade, or to the method by parallel courses, making the ships change course through the angle $90° + \frac{\omega}{2} - \beta_1$ in a way that may result in the direction AP, B afterwards executing the reduction of speed. With this latter method the relative speed is $V_A - V_B$; and hence the time necessary for the evolution remains at that corresponding to the method above indicated (AP being always the same) in the ratio $\frac{V_r}{V_A - V_B}$, by virtue of equation (1) of Section 31. Hence it is evident that the evolution by the method of parallel courses can never occupy less time than that which is required by the other method, which we will call *the method by oblique courses.*

A general rule—which we shall suppose to be implicitly followed in the evolutions when nothing is specified to the contrary—is that the ship B at the beginning of the evolution (or before reducing the speed) makes the two changes of course (initial and final) that A makes at A and at A'; with this rule, mentioned by Admiral de Gueydon,† the displacements due to changes of course are rendered the same for A and for B.

III. *Definitions.*—If two ships have the same course and speed, and the one further advanced in the direction of the course is bearing from the other at an angle α from the bow, we say that it is on the *line of polar bearing* α.

By *wheeling a line of polar bearing* we mean the evolution by oblique courses which permits of rotating the line joining the two ships, at the end of which rotation the former polar bearing of the formation is re-established.

* PESCI: Sui metodi per cambiare il rilevamento fra le navi di una formazione semplice, *Rivista Marittima,* March, 1897.

† Tactique Navale. Recherche des principes primordiaux et fondamentaux de toute tactique navale (1868).

Fig. 17 shows a line of bearing that executes a wheel through an amplitude ω. The ship B—which is the one situated on the side toward which the wheel is to be executed—changes to the course BI', which makes with the original course BI the angle ω in the direction of the wheel; after this B reduces the speed, assuming a speed V_B, while A maintains the evolutionary speed, which we will designate by V^A. In order that the distance at the end of the evolution may be the normal distance, the indicator of movement must be AP, such that $PAB = 90° - \frac{\omega}{2}$; so that the course that A must follow is AA'. When A has nearly arrived at

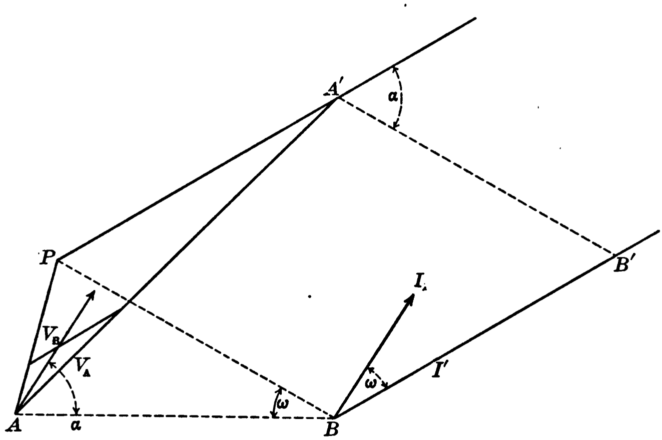


FIG. 17.

the position A', it changes to a course parallel to BI', while B again takes up the normal speed.

Evidently this problem is but a particular case of the one before presented, and, in its turn, the problem of wheeling a column of vessels is a particular case of this one. In such particular case the choice of the pivot ship is optional; that is, the line may be made to wheel about the rear ship or about the leading ship.

In 1905 we were led to consider the wheeling of a column of vessels by reading an important article entitled, *Notes on the Principles of Naval Tactics,* which appeared in the September number for that year of the *United Service Magazine,* signed by the pseudonym *Experience.* In the said article mention is made

of pivoting the line at one-third of its length from the leading vessel; we shall occupy ourselves with this problem hereinafter.

In wheeling the column, while the pivot ship turns through the angle ω in the direction of the wheel, the other ship must change from the original direction through an angle $\phi=\omega+\delta$, δ being the angle given by equation (3); the angle ϕ is positive or negative according as the change of course is made in the direction of the wheel or in the opposite direction.

Let us indicate by ϕ_c and ϕ_t the respective values of ϕ for the wheel on the rear ship and that on the leading one.

In the first case the value of δ is determined, bearing in mind that the pivot ship changes course through the angle ω, and that hence, in equation (3), it is necessary to put $\beta_1=\omega$; in this way we get

$$\delta=90^\circ-\frac{\omega}{2}-\text{arc sin}\left(\frac{V_B}{V_A}\cos\frac{\omega}{2}\right),$$

and hence

$$\phi_c=90^\circ+\frac{\omega}{2}-\text{arc sin}\left(\frac{V_B}{V_A}\cos\frac{\omega}{2}\right). \tag{4}$$

For the wheel with the leading vessel as a pivot it is necessary to substitute in equation (3)

$$\beta_1=180+\omega,$$

from which we obtain

$$-\phi_t=90^\circ-\frac{\omega}{2}-\text{arc sin}\left(\frac{V_B}{V_A}\cos\frac{\omega}{2}\right).$$

Taking absolute values for ϕ_c and ϕ_t we get

$$\phi_c-\phi_t=\omega, \tag{5}$$

which, together with equation (4), permits of the construction of a table which will give the angle of the change of course for a given speed ratio.

From equation (5) it is clear that, in order to apply the rule of De Gueydon, the pivot ship, in wheeling on the rear vessel, must change course through ϕ_c in the direction of the wheel, and afterwards execute a change through ϕ_t in the opposite direction; in the case of pivoting on the leading ship, the pivot ship must change course through ϕ_t in the direction opposite that of the wheel, and afterwards through ϕ_c in the direction of the wheel.

IV. By equation (1) of Section 31, the time necessary for executing a change of bearing (or a wheel) of an amplitude ω, is

$$t = \frac{AP}{V_r} = \frac{2AB \sin \frac{\omega}{2}}{V_r}, \tag{6}$$

from which it is seen that *the duration of the evolution is proportional to the length AB of the line or column.**

Let us now compare the rapidity of wheeling a column of vessels by the two methods indicated.

Let B be the pivot ship (Fig. 18). According as the ship A is at A_2 or at A_1—that is to say, ahead or astern of the pivot—in order to wheel the line through ω, we find ourselves in the case of pivoting on the rear or on the head.

A_2' and A_1' being the corresponding positions of A at the end of the evolution, let us determine what must be the ratio $\frac{A_1B}{A_2B}$, to the end that we may have $A_2A_2' = A_1A_1'$. By virtue of the proportionality before mentioned, this ratio indicates the relative rapidity of the two methods, which we will indicate by $\frac{t_2}{t_1}$, t_2 and t_1 being the times respectively employed in the case of pivoting on the rear and on the head.

Considering the triangles A_1BA_1', A_2BA_2', by equation (5), we have

$$A_2A_2'B = \phi_t; \quad X_1A_1'B = \phi_c;$$

and hence

$$\frac{\sin \phi_t}{A_2B} = \frac{\sin \omega}{A_2A_2'}; \quad \frac{\sin \phi_c}{A_1B} = \frac{\sin \omega}{A_1A_1'},$$

* The ratio between the times necessary for the evolution by the method of parallel courses and by that of changing direction in succession is

$$\frac{2 \sin \frac{\omega}{2}}{V_A - V_B} V_A,$$

or the first of these methods is more rapid if

$$\sin \frac{\omega}{2} \leq \frac{1 - \frac{V_B}{V_A}}{2}.$$

With this formula, for $\frac{V_B}{V_A} = \frac{1}{2}$, $\omega \leq 29°$; for $\frac{V_B}{V_A} = \frac{8}{10}$, $\omega \leq 12°$. Then, from what has been said in division II, the evolution by oblique courses is proper in limits wider than these. (Author's note.)

from which—as, by hypothesis, $A_2A_2'=A_1A_1'$—we obtain

$$\frac{A_1B}{A_2B}=\frac{\sin\phi_c}{\sin\phi_t}.$$

Calculating ϕ_c and ϕ_t by means of equations (4) and (5), we deduce from this formula the values of the ratio $\frac{A_1B}{A_2B}$, which

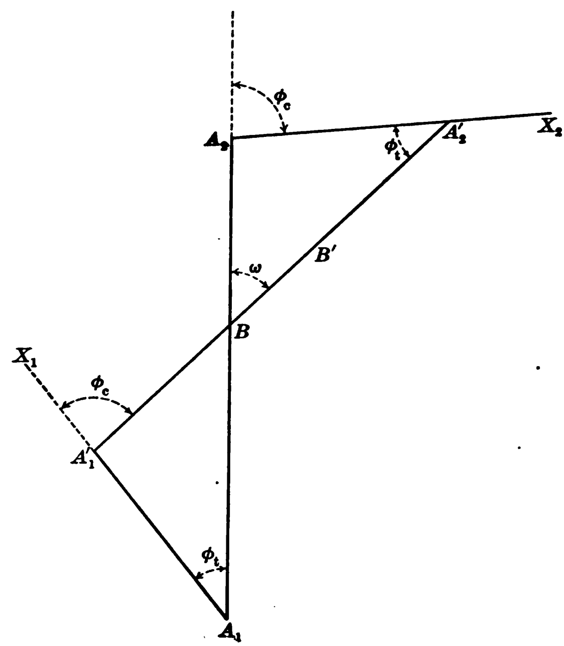


FIG. 18.

values, set down here below opposite ω, are determined under the hypothesis that $\frac{V_B}{V_A}=\frac{1}{2}$.

ω	$\frac{t_2}{t_1}$
15°	1.16
30°	1.35
45°	1.57
60°	1.78
75°	2.00
90°	2.24

It results from this table that the greater rapidity is obtained by pivoting on the head; by the other method, for the supposed speed ratio, about double the time is employed if ω is between 60° and 90°, and one and a half times more if ω is between 30° and 45°.*

Let us now consider the time required for changing the direction of the line through the angle ω by changing course in succession, and compare it with that required by a wheel with a pivot at the head; setting aside the time employed in changes of course.

Indicating by t_0 the time required for the change of direction by changing course in succession, we have

$$t_0 = \frac{AB}{V_A}, \tag{7}$$

while the time required for the wheel is given by equation (6); hence

$$\frac{t_1}{t_0} = \frac{2 V_A \sin \frac{\omega}{2}}{V_r}.$$

In the case we are considering (pivoting on the head), in the formula of Section 31, which gives V_r, it is necessary to put

$$\alpha = \phi_t; \quad \beta = 180° - \omega;$$

and by equation (5) we obtain

$$\alpha - \beta = \phi_c - 180°;$$

therefore we have

$$V = V_A \sqrt{1 + \left(\frac{V_B}{V_A}\right)^2 - 2 \frac{V_B}{V_A} \cos \phi_c}.$$

There results, then,

$$\frac{t_1}{t_0} = \frac{2 \sin \frac{\omega}{2}}{\sqrt{1 + \left(\frac{V_B}{V_A}\right)^2 - 2 \frac{V_B}{V_A} \cos \phi_c}}.$$

* It is easily seen that $\frac{t_2}{t_1}$ increases the more $\frac{V_B}{V_A}$ approximates to unity. It is well to note that, in any evolution, we may not adopt in practice a ratio $\frac{V_B}{V_A}$ less than ½; indeed it must be remembered that the speed of the pivot ship is not instantaneously reduced, and hence, in order to have the mean speed V_B during the evolution, the engine must be regulated for a lower speed. (Author's note.)

With this formula, for $\frac{V_B}{V_A} = \frac{1}{2}$, there are calculated the values of $\frac{t_1}{t_0}$ set down in the following table, in which are also written the values of $\frac{t_2}{t_0}$ obtained by multiplying the values of $\frac{t_1}{t_0}$ by the corresponding values of $\frac{t_2}{t_1}$ given in the preceding table.

ω	$\frac{t_1}{t_0}$	$\frac{t_2}{t_0}$
15°	0.28	0.32
30°	0.51	0.69
45°	0.71	1.11
60°	0.86	1.53
75°	0.99	1.98
90°	1.09	2.44

Having regard to the rapidity and to the simplicity of the evolution, and reserving it to ourselves to discuss the subject in relation to the movements of the enemy, this table permits us to announce the following conclusions:

1st. *When ω is greater than 30°, a change of course in succession is preferable to a wheel on the rear ship.*

2d. *A wheel on the leading ship may be preferred to a change of course in succession when ω is within the limit of 60°.*

Within the limits thus established, indicating by t a value of t_1 or of t_2, and t_0 being the corresponding value given by equation (7), putting $\frac{t}{t_0} = m$, we have

$$t_0 - t = \frac{AB}{V_A}(1 - m).$$

The gain in time permitted by a wheel is then directly proportional to the length of the line.

34. *Determination of the Course and of the Speed of the Enemy.*—I. The principal force (or the main body of the fleet), on information from the units that keep the enemy in sight and determine his course and speed with the closest approximation possible, can execute the maneuver of approach in the way indicated in Sections 32, II, and 33, I.

The preliminary problem reduces itself to the hypothesis of a ship, A, that wishes to determine the course and the speed of another ship, B.

With this object in view, the ship A keeps on a constant course

and, at any interval, *t*, of some minutes, it repeats the measurement of the distance and the polar bearing on which *B* lies. Drawing the triangle $AA_1'B$ (Fig. 12), wherein AB and $A_1'B$ represent two measured distances, and the angle at *B* is the difference between the corresponding bearings, the line AA_1' is the indicator of movement; consequently, marking on the drawing the course of *A* and taking on it the segment AA_1, equal to the distance passed over by the ship in the time *t*, the segment $A_1'A_1$ will represent, in direction, the course of *B*, and in length, the distance passed over by the said ship in the said time.

With these measurements, two values for the course as well as for the speed sought may thus be obtained; hence, the mean of these may be taken, and so proceeding, an approximation may be reached which is so much the closer, the greater the number of measurements made.

But we note that, under the circumstances in which the problem must be solved, the distance AB may be predicted to be in the neighborhood of 15,000 meters, and may be even greater; hence but scant confidence can be placed in the accuracy of the indications supplied by the range finders. For this reason it is well to observe that, in the determination of the elements we are seeking, we may proceed with a graphic method, based upon the measured polar bearings and the spaces passed over in the intervals, supposing the distance to be only roughly known.

For this very simple method, devised by Lieutenant P. Corridori, it is expedient: 1st, to follow a course that is not parallel to that of *B*; 2d, that, considering the surface of the sea to be divided into two parts by the joining line *AB*, the two courses be *not* directed toward the same side of the line.

This being said, here, in a word, is the method: We mark off on a straight line which represents the track of *A* (Fig. 19) the points A, A_1, A_2, ... corresponding to the space passed over in the interval established between the successive measurements, and then we draw from these points the straight lines AB, A_1B_1, A_2B_2, ... forming with the above-mentioned line the measured polar bearings.

With a graduated ruler, estimating by eye the direction followed by *B* with respect to *A*, we seek, by trials, to find the position that the ruler must assume in order that the segments BB_1, B_1B_2 . . . . may be equal among themselves. Such a position

of the rule is the line of the course of B, and the scale of the drawing supplies his speed.*

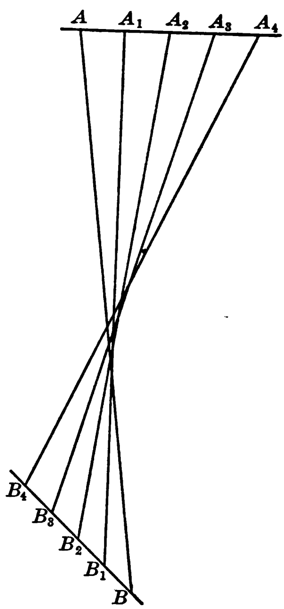


FIG. 19.

Having a fairly good knowledge of the distance, the two methods above indicated may be combined; in other words, AB and A_1B_1 being marked down, taking into account the first two distances measured, we place the ruler in the direction of BB_1. When the next measurement permits of marking down A_2B_2, we determine a more approximate position of the rule, so that BB_1 may be equal to B_1B_2, and so on.

II. When the fighting forces that have to execute the movements corresponding to the preceding sections are in sight of the enemy, it is obvious that they may not delay beginning those movements in order to determine his course and speed; but it is well to take an approximate course, keeping it constant for some minutes, in order to attempt such a determination by the first of the methods just pointed out, and afterwards be governed by the established rules.

* Evidently if the successive joining lines were all to intersect in one and the same point at a distance finite or infinite (parallelism), the position of the rule would be indeterminate. It is to be noted that theoretically this indetermination exists in any case because the curve traced through the intersections of the joining lines AB, A_1B_1, A_2B_2, ... is a parabola; consequently an error in the initial distance AB produces errors in the speed and in the course. However, when the angle between the courses is within opportune limits, the above-mentioned errors are very small, even when the distance is very roughly known; for example, when a distance of about 15,000 meters is estimated with an approximation of ± 2000 meters.

If the polar bearing were exactly measured, for the application of the method, it would suffice to limit the said measurements to three; but on account of the inevitable errors it is well to take at least five or six bearings, well distanced, for example, at intervals of five minutes. Concerning the probability of so doing it is well to bear in mind that in contact out of range, when the naval forces are not in sight of each other, the course and the speed will not be frequently changed. (Author's note.)

35. *Fundamental Tactical Relation.*—In order to establish criteria of practical utility, the study of the offensive contact must be made in the most general form, considering the supposed adversary free at any moment to keep our ship on the bearing that he may deem most advisable.*

The basis for the study of the types of maneuvering that we shall develop in the following chapters must be sought in a general relation that shall bind together the *elements of movement* of the two ships; that is to say, the respective speeds, the polar bearings, and the variation of the distance. To such a relation we shall give the name of *fundamental tactical relation.*

Two ships, A and B, follow any two tracks. At the moment we are considering, they have the respective speeds V_A and V_B, and they have each other on the bearings α and β from the bow.

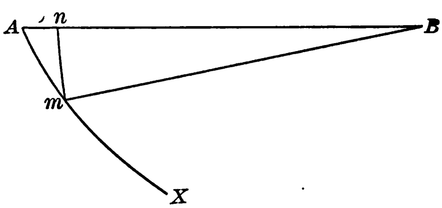


FIG. 20.

The indicator of movement is a curve AX (Fig. 20), of which the tangent at A, which is the direction of the relative speed V_r, forms with AB an angle which we indicate by δ.

If m is a point on the indicator infinitely near to A, describing the arc mn of a circle with its center at B, the triangle Amn may be considered a right triangle, right angled at n; hence

$$An = Am \cos \delta.$$

Letting dr and dt be respectively the differentials of the distance and of the time, since dr is negative when a diminution of the distance is produced, by substituting for An and Am their values, we have

$$dr = -V_r \cos \delta dt.$$

* Suppose, for example, that the enemy follows a constant course, or some other track of geometrically determined form, it is well understood how a proper measure might easily be decided upon; but such a deduction would be of small importance, because it would be based upon too particular a hypothesis. (Author's note.)

Projecting V_r and its components, V_A and V_B, upon AB, as the projection of the resultant is equal to the algebraic sum of the projections of the components, we obtain

$$V_r \cos \delta = V_A \cos \alpha + V_B \cos \beta.$$

Substituting in the preceding equation, there results

$$\frac{d_r}{d_t} = -(V_A \cos \alpha + V_B \cos \beta),$$

which is the relation sought. Putting

$$\theta = 180° - \beta,$$

the fundamental relation may be written

$$\frac{d_r}{d_t} = V_B \cos \theta - V_A \cos \alpha,$$

in which it is to be remembered that θ is counted from the stern and α is counted from the bow.

36. *Constant Bearings.*—If the two ships A and B do not alter their speed, and steer on constant polar bearings, $\frac{d_r}{d}$, or the variation of the distance in the unit of time, also becomes constant, and hence the distance varies proportionally to the time.*

In case the speeds are constant, but the polar bearings are variable, the fundamental relation gives the variation of the distance in a time sufficiently short to enable us to consider α and θ as practically constant during that time. Let us see what may logically be held to be the variability of the elements of movement.

Trusting to our dexterity in firing, we may propose to ourselves to cause the distance to vary rapidly; that is to say, to render $\frac{d_r}{d_t}$ the maximum. It is well to observe, however, that we control our polar bearing and our speed; that is to say, only one of the

* It is to be noted that when the speeds and bearings are constant, V_r and δ become constant; the indicator of movement of one ship with respect to the other thus cuts the straight lines drawn from its initial point at a constant angle; it is, then, an equiangular or logarithmic spiral, the pole of which is in the said initial position. The spiral naturally becomes a circle when the distance is kept constant, and is reduced to a straight line when the conditions of movement cause the ships to arrive simultaneously at the point of intersection of their attacks, or when the two ships may be considered as setting out simultaneously from the said point. (Author's note.)

terms of the second member of the fundamental relation. Well and good; by keeping the enemy on a variable polar bearing we shall not be able to oblige him to do likewise, and we shall renounce important benefits. In fact, a constant bearing may opportunely be chosen (Part I, Chapter I); moreover, it facilitates the control and the execution of the firing. The control is advantaged since it must necessarily be based upon the hypothesis that the variation of the distance in the interval between two successive salvos is approximately constant, and certainly the fact that we do not change the gun pointing in direction is good for the execution of the firing.

It is very probable that the enemy also may maneuver well; that is, he may be inspired by the same ideas. In studying the types of maneuvering we shall not exclude the possibility of his withdrawal; but meanwhile *it may be held to be a sufficiently general hypothesis that* α *and* θ *do not change for a certain time.* With regard to the speed, it is evidently important to vary it as little as possible.

37. *Curvature of the Ship's Track.*—It is now expedient to ascertain whether the movement on a constant polar bearing may in any case produce sensible disturbance to the firing.

The ship *A*, when the enemy *B* has him bearing at an angle θ —to port, for example—produces, by virtue of the fundamental relation, the same variation of distance whether he keeps *B* bearing at the sight vane angle α to starboard or to port; because, in that way, the values of α to be introduced into the fundamental relation are equal and with contrary signs; that is to say, $\cos\alpha$ does not change. However, according as *A* keeps *B* at an angle α, presenting to the fire of the enemy the starboard or the port side, it changes, not only the track of *A*, but also that of *B;* although the side that the latter presents may be the same in both cases.

Let us indicate by ρ'_A and ρ'_B the radii of curvature of the tracks of *A* and *B* at a given instant, in case the ships present to the fire sides of opposite names; while ρ''_A and ρ''_B indicate the radii in the case in which the ships present sides of the same name.

As, by hypothesis, the bearings are kept constant, the angle through which *A* and *B* change course in a given time is the same; and is equal to the angle through which the line joining the adversaries rotates. Let $d\sigma'$ be the said angle for the movement

in the time dt, with sides of opposite names, while we indicate its value in the movement with sides of the same name by $d\sigma''$. Denoting by dS_A and dS_B respectively the differentials of the arcs of the tracks of A and B, there results

$$\left.\begin{array}{l} dS_A = \rho'_A d\sigma' = \rho''_A d\sigma'' = V_A\,dt \\ dS_B = \rho'_B d\sigma' = \rho''_B d\sigma'' = V_B\,dt \end{array}\right\}, \tag{8}$$

and hence

$$\frac{\rho'_A}{\rho'_B} = \frac{\rho''_A}{\rho''_B} = \frac{V_A}{V_B}. \tag{8}$$

We may then affirm that, *at any instant, the ratio of the radii of curvature of the tracks is constant and equal to the ratio of the speeds.*

Indicating by ρ' the radius ρ'_A or ρ'_B, and by ρ'' the corresponding ρ''_A and ρ''_B, there results from (8)

$$\frac{\rho'}{\rho''} = \frac{d\sigma''}{d\sigma'}. \tag{9}$$

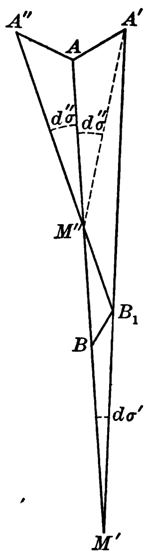


FIG. 21.

This being the case, let B_1 (Fig. 21) be the position of B after the interval of time dt, and let A' and A'' be the corresponding positions at which A arrives according as he selects the movement with the side of opposite name or with the side of the same name.

Prolonging AB and $A'B_1$ to their intersection at M', and calling M'' the point of intersection of AB and $A''B_1$, we have

$$AM'A' = d\sigma', \quad A''M''A = d\sigma'';$$

but since by hypothesis

$$A''AB = A'AB = \alpha,$$

we have also

$$AM''A' = d\sigma''.$$

The angle $d\sigma''$ being thus an exterior angle of the triangle $A'M''M'$, we have

$$d\sigma'' > d\sigma';$$

and hence, by equation (9),

$$\rho'' < \rho'.$$

It is thus established that, *if a ship fights presenting to fire the side of the same name as that of the enemy, the radius of curvature of its track is at any moment less than it would be if, with the same sight-vane angle, the ship should present the side of the contrary name. The rotation of the joining line is more rapid.**

With the object of completely fixing the ideas concerning the subject we are discussing, it is sufficient to have recourse to the relation that gives the value of $\frac{d\sigma}{dt}$, which is determined in a manner analogous to that of the fundamental relation, as follows:

In order to get the angular displacement in the time dt of the line joining the two adversaries, we observe that the length of the arc corresponding to the angle—that is, $rd\sigma$—is equal to the difference of the displacements normal to the joining line in case the sides presented are of opposite names, and to their sum in case the sides presented are of the same name; we have then,

$$\frac{d\sigma}{dt} = \frac{V_A \sin \alpha \mp V_B \sin \theta}{r}, \tag{10}$$

wherein the negative sign corresponds to σ' and the positive sign to σ''.†

We observe that there results from (8)

$$\rho = \frac{V}{\frac{d\sigma}{dt}},$$

V indicating the speed of the ship A or that of B, and ρ the corresponding radius of curvature. Substituting for $\frac{d\sigma}{dt}$ its value, given by (10), we get

$$\rho = \frac{V}{V_A \sin \alpha \mp V_B \sin \theta} r, \tag{11}$$

* Evidently we may also reach this deduction when referring to the relative speed. When A and B present to fire sides of the same name, the relative speed is greater than in the other case, and is nearer to the direction normal to the joining line AB. (Author's note.)

† The values of σ' deduced from this relation are positive when the ship A sees the line joining it with the enemy inclined in the direction in which the ship is moving; they are negative in the opposite case, which is realized when

$$V_A \sin \alpha < V_B \sin \theta.$$

(Author's note.)

which confirms the preceding results, and demonstrates further that *the radius of curvature varies proportionally to the distance.* This relation is the one sought and upon which we may base conclusions.

When we say that the changes of course disturb the firing we have reference to the changes with the helm hard over, or with a radius of 400 or 500 meters; this is the limit to which it is necessary to compare the radii of curvature of the tracks.

Referring to the case in which the adversaries present sides of the same name—that is, to the case in which the radii are shorter —it is necessary to establish whether they are great enough not to affect the fire control.

Let us, then, consider the values of ρ'', laying down the observation that, while the values of ρ are different in the case of sides of opposite names and in that of sides of the same name, their ratio, by virtue of (8′), is constant; that is, the relative conditions of the adversaries do not change, and, for the values that the speed ratio may have in practice, these conditions may be held not to differ sensibly.

We will therefore consider the values of ρ''_B, supposing B to be the slower ship; these are given by (10), making therein $V = V_B$, and taking the positive sign in the denominator. Let us refer to a ratio $\frac{V_A}{V_B} = \frac{1}{2}$, and to a single, $r = 500$ meters; because, for the other values of the distance, it is sufficient to take into account the proportionality between ρ and r. Given the ordinary amplitude of the sectors of maximum offense (45° forward of and 45° abaft the beam), we may limit ourselves to varying a and θ between 45° and 90°, because the values of ρ''_B that are realized in the other cases enter into those that are deduced with the preceding data.

VALUES OF ρ''_B (METERS).

θ \ a	45°	60°	90°
45°	3210	2860	2620
60°	2910	2620	2420
90°	2700	2450	2270

These values show that, *in long-range battle, the radii of curvature, when steering on a constant bearing, have in any case values so considerable as to exclude disturbance of the firing; rather, the*

values of ρ'' are such that steering by sight vane may be adopted, even against an enemy who keeps his course unchanged.

In closing the distance the values of ρ'' diminish in a way to cause disturbance to the firing, while the values of ρ' are always very large; in fact, it is enough to bear in mind that the minimum ρ' is 5060 meters, which in practice (under the logical hypothesis that B fires with a maximum number of guns) corresponds to $\theta=45°$ and $\alpha=90°$, for $r=2500$. *Hence, at close range we may steer by sight vane, presenting to fire the side of the name opposite that of the enemy; when presenting the side of the same name we must steer rectilinear courses.*

CHAPTER II.

MANEUVERS OF TWO SHIPS OPPOSED TO EACH OTHER.

38. *Importance of the Study of the Naval Duel.*—In this chapter we propose to study the maneuvers of two ships opposed to each other, excluding the case of the attack upon a battleship by a torpedo boat, which will be discussed hereafter.

First of all, it is well to reflect that there is but scant probability of single combats, considering that the more important a ship is, the less rational will be its isolation. Thus, in order to increase the zone explored by a fleet, we might be induced to extend the battleships also in chain, as well as the cruisers. This might seem to be advisable if our ships possessed a speed superior to that of the enemy's similar ships, so as to be able to effect concentration in good time. But such advisability must be excluded, because the conditions under which the meeting with the enemy will take place can never be foreseen. Without need of entering into discussions of a strategic character, as an elementary measure of precaution we may establish the general rule that the battleships should cruise together, and that the armored cruisers should be able to rejoin the main body with facility. Only on account of the material and moral superiority that one has in the pursuit which succeeds a victorious battle, can it be permissible to abandon, at least in part, those precautions that are indispensable in the presence of an enemy in full efficiency.

Duels, then, are to be predicted between the lighter ships; nevertheless, it is not expedient to limit ourselves to examining the hypothesis that may be formulated in this respect. The study of combat between two ships furnished with vertical armor, powerfully armed and protected (battleships or armored cruisers), if it is of improbable practical application, is of importance to us because it serves as a starting point for the study of squadron combat. Indeed, in maneuvering a fleet, the ideal at which it is necessary to aim is that of securing an advantageous position with respect to the enemy, minimizing for each ship the hindrances that derive from its association with the others; or, it is necessary that the maneuvers of each ship, with respect to

that of the enemy upon which it is directing its fire, should approximate, as far as possible, to the maneuvers that it would make if it were alone.

Thus there results the advisability of studying the naval duel in a general way. We shall suppose that the maneuvering is not hampered by the coast or by other causes, and afterwards we shall allude to some special cases.

39. *Distance Kept within Limits and Constant Distance.*—It is clear that the maneuvering of our ships in long-range battle must *generally* satisfy the conditions of keeping the enemy bearing in a sector of maximum offense. Subordinately to this, in whatever way the enemy may maneuver, the maneuvering may be intended either to preserve the distance that one has at the actual moment, or to change it.

Let us now consider the first of these hypotheses. We have recognized (Part I, Chapter IV) the impossibility of assigning a strictly determined value to the distance of maximum utilization; we likewise know (Part I, Chapter I) that the directions of maximum utilization are to be considered as elements of the highest importance for tactical maneuvering. Hence, it would seem logical to establish that the maneuvering should be developed by keeping the enemy in directions of maximum utilization alternately forward of and abaft the beam; in this way the conservation of the distance that is deemed favorable for our ship should be understood in the sense of causing it to vary, keeping its variation, however, within the limits of the zone of maximum utilization. This form of maneuvering, which is called *maneuvering with limited distance,* cannot be established in an absolute way. In fact, it evidently leads to changes of course that disturb the firing when one passes from the bearing forward of the beam to that abaft the beam or vice versa; and, furthermore, one is obliged to present the beam at such moments; further still, one of the two phases, either that of the bearing forward of the beam or that of the bearing abaft the beam, will be very short, as may easily be seen by calculating (with the fundamental relation) how rapidly the distance varies between two ships that keep each other bearing in the same general direction from the beam.

From this arises the idea of ***keeping constant some value of the distance included in the zone of maximum utilization, on a suitable polar bearing,*** whenever this may be possible.*

Evidently, the first condition necessary in order that the distance may be constant, is that of keeping the enemy bearing abaft the beam when he has us bearing forward of the beam, or vice versa.

The necessary relation between the speeds and the polar bearings in this form of movement is that which, in the fundamental relation, makes $\frac{dr}{dt}=0$; that is to say:

$$V_A \cos \alpha = V_B \cos \theta,$$

* The French admiral, Fournier, in his book called "La flotte necessaire" (1896), was the first to study the combat with limited distance, putting the question in the following terms: The task of the vessel that wishes to draw profit from an advantage in speed is to maneuver, presenting his side in such a way as always to keep his adversary at the most effective range of his guns, without allowing him to approach within a distance arbitrarily fixed as the limit of safety. He studies the maneuver of the swifter ship on the basis of the following theorem: If two ships having speeds V_A and V_B ($V_A > V_B$) start at a distance r_0, and the swifter vessel follows a logarithmic spiral with its pole in the initial position of the slower ship, and inclined to the radii vectors in such a way as to keep the pole bearing at an angle whose cosine is $-\frac{V_B}{V_A}$, while the slower ship steers on a radius vector, the distance between the two ships varies until it returns to r_0, when the swifter ship passes ahead of the other. Fournier based himself on the hypothesis that the slower party, with the intention of diminishing the distance, might follow a rectilinear course, or keep his bow constantly on the enemy. In consequence of this, and of the fact that the faster ship, which passes over arcs of a logarithmic spiral conformably to the theorem aforesaid, has not the enemy constantly bearing in a sector of maximum offense, the maneuver with limited distance in the way proposed by Fournier is not acceptable. (See our study entitled "La velocita nella tattica navale," in *Rivista Marittima* of January, 1900). Nevertheless, Fournier's book efficaciously contributed to the progress of Tactics by initiating the study of long-range battle. Following Fournier came Commander (now Admiral) Baggio-Ducarne, who, studying the application of Fournier's criteria (*Rivista Marittima,* April, 1897), adjudged to Admiral Saint-Bon the merit of having, in 1885, perceived and demonstrated, in a tactical exercise, the advantage that a ship, swifter and more powerful than another, may draw from long-range battle. Comandante Ronca first pointed out the convenience of keeping the distance constant (*Rivista Marittima,* June, 1897). (Author's note.)

which we will call *the equation of constant distance.* It results from this that, theoretically, a ship, *A,* can maneuver at a constant distance from another ship, *B,* in two ways: 1st, at a *constant speed,* pre-establishing V_A, and determining the polar bearing α on which he must keep the enemy by means of the equation

$$\cos \alpha = \frac{V_B}{V_A} \cos \theta,$$

so that α is constant if B keeps θ and V_B constant; 2d, on a *constant bearing,* pre-establishing the polar bearing in which the enemy must be kept, and assuming the speed

$$V_A = \frac{V_B \cos \theta}{\cos \alpha},$$

so that V_A is constant if B keeps θ and V_B constant.

Each of these methods presents grave inconveniences. Brief considerations suffice to show that, in general, *with one of the above-mentioned methods, if the maneuvering of the enemy is not rational, our maneuvering also cannot be the most opportune.*

With the method at a constant speed, if B keeps A on a variable bearing, θ (as may happen, for example, when B keeps the course constant), α must also be variable. If $\theta = 90°$, α must also be $90°$; corresponding to $\theta = 0$ and $\theta = 180°$, we have, respectively, $\cos \alpha = \frac{V_B}{V_A}$ and $\cos \alpha = -\frac{V_B}{V_A}$. Consequently, if the enemy should constantly present his beam, in applying this method our ship should act in the same manner, which is illogical. If the enemy has our ship bearing in line with the keel or in a sector of minimum offense, with the values that the speed ratio may assume in practice, our polar bearing also would generally be outside of a sector of maximum offense. Moreover, if $V_A > V_B$, $\cos \alpha < \cos \theta$; and hence, supposing B to maneuver rationally and keep A in a direction of maximum utilization, the ship A, in order to keep the distance constant and develop the maximum speed, must bring the enemy to bear nearer to the beam, or, in a direction that may be a less defensive one.

With the method on a constant bearing it might be necessary to vary the speed between very wide limits; that is to say, from the value $\frac{V_B}{\cos \alpha}$ to the value *zero* corresponding to $\theta = 90°$.

Neither of these forms of maneuvering can, in an absolute way, be held to be acceptable, as has already been said concern-

ing that with the limited distance; but, instead, it will be easy to see how the three methods, considered together, permit of formulating practical rules of great simplicity.

We may reach such rules with the aid of the following observations:

I. It would be absurd to vary the speed in the way that might be required by the method on a constant bearing, but limited variations of the speed, from the maximum to a speed inferior by four or five knots, are acceptable.

II. Analogously, it may be admitted that our sight vane may be moved from a direction of maximum utilization as much as 15° or 20°, approaching nearer to the beam, or reaching an extreme limit of the sectors of maximum offense.

III. When the enemy keeps our ship bearing in a direction very near the beam, the variation of the speed and of the bearing within the limits above mentioned is not sufficient to keep the distance constant; maneuvering with a limited distance is then rendered necessary, and we need not be concerned about having to present the beam at intervals, because the enemy is continually in that disadvantageous condition.

IV. When the enemy, for reasons that we shall specify, can control the variation of the distance and avails himself of that faculty, it is evidently necessary to develop the maximum speed and steer with the sight vane on an extreme limit of the sectors of maximum offense, thus hindering the maneuvering of the enemy as much as possible. This being said, the rules for the practical application of the criteria alluded to are evident.

40. *Maneuvering in Long-Range Battle.*—Our ship is, by hypothesis, within the limits of distance that are held to be advisable. We have the usual disk provided with a sight vane. On it, *PP'* (Fig. 22) indicates the direction of the keel; *OS* and *OS'* are the limit directions of the sector of maximum offense *SOS'*.

Let us suppose that the enemy has our ship bearing forward of the beam. We steer on a constant bearing, arranging the sight vane in the direction *OM*, which is the after direction of maximum utilization, and we develop the maximum speed.

Three cases may present themselves; that is to say, the distance may remain constant, or it may increase, or it may diminish.

In the first case we have but to continue to steer with the sight vane in the direction *OM*.

In the second case, that is, when the distance increases, continuing to steer with the sight vane on *OM,* we reduce the speed little by little, and it is possible that, within the limits established for the diminution (four or five knots), we may find a speed that will keep the distance constant. When this is not realized, even for the said inferior limit of the speed, we gradually move the sight vane nearer to the beam, without, however, going beyond

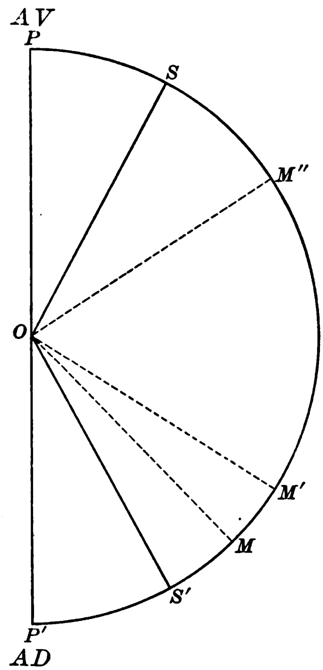


FIG. 22.

the pre-established limit *OM′*. If, even with this limit direction, the distance still increases, we continue to steer with the sight vane in the direction *OM′* and, before arriving at the superior limit of the distance, we change our course, steering at the minimum speed with the sight vane in the direction *OM″* symmetrical with *OM′*.

In the third case, that is to say, when the distance diminishes, keeping to the maximum speed, we move the sight vane gradually toward *OS′*. This limit being reached, if the distance continues to diminish, we may not move the sight vane further toward the

stern, because that would be without the sector of maximum offense. Evidently the enemy is master of the maneuvering, and we must continue to steer with the sight vane in the aforesaid direction in order to minimize the variation of the distance. We should maneuver in a perfectly analogous manner if the enemy had our ship bearing abaft the beam.

41. *Rotation of the Line Joining the Adversaries.*—It results from the foregoing that, with two adversaries that maneuver rationally, besides being able to presume that they may steer maintaining constant polar bearings, the *typical case* to be considered is that wherein, for a certain time, the distance remains about constant.

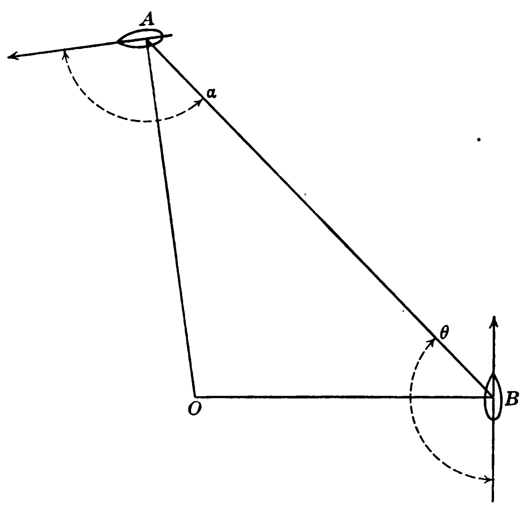


FIG. 23.

It is easily demonstrated that, *if two ships steer keeping constant polar bearings, and if the distance also remains constant, the tracks followed by the two adversaries are concentric circumferences.* In fact, by equation (11) of Chapter I (Section 37) the radii of curvature of the tracks described by the ships A and B in the case we are now considering are constant, and hence the tracks are circumferences; moreover, the normals to the tracks always intersect in a point O (Fig. 23), by which we have

$$\frac{OA}{OB} = \frac{\cos\theta}{\cos\alpha},$$

and hence, from the equation of constant distance, there results

$$\frac{OA}{OB} = \frac{V_A}{V_B},$$

and O is then the common center.

Fig. 24 shows the circumferences passed over by ships supposed to be initially at A and B; the centers O' and O'' of the circumferences that the ships follow in presenting sides of the same name or sides of opposite names are naturally found on the perpendicular to the initial course of the ship B, which is supposed to have A always bearing to port. Conformably to

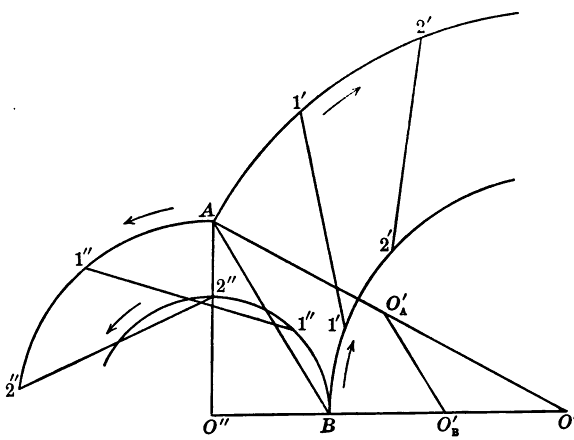


FIG. 24.

what has been demonstrated in a general way in Section 37, the radii of the circumferences with their center in O'' are shorter than those of the circumferences that have their center in O'; and hence, in the movement with sides of the same name, the rotation of the line joining the adversaries is more rapid; which is important in relation to what is said in Section 21 concerning the natural elements.*

* The demonstration that the tracks of A and B in the case under consideration are concentric circumferences can also be made without having recourse to the aforesaid formula (11). In fact, if the center of curvature of the tracks of A and B were not coincident and fixed, they would be, for example, at O'_A and O'_B on the respective normals to the tracks; and by virtue of equation (8') of Chapter I, and of the equation of constant dis-

The expediency of presenting to the enemy the proper side in order to keep or to secure an advantageous position with respect to the sun, or to the coast, or to the strategic objectives, is clear; therefore it is important to fix the ideas concerning the rapidity of rotation of the joining line.

The speeds, the polar bearings and the distance being constant, it results from equation (10) of Chapter I that *the speed of rotation of the line joining the adversaries is constant.* With the said formula we may calculate the time required for the joining line to rotate through a given angle.

We note that, if the speeds of A and B are equal, or, if $\alpha=\theta$, the point O' is at infinity, and the tracks of the two ships are parallel straight lines; while the circumferences with their center at O'' are reduced to one only, since $\rho_A = \rho_B$. This being the case it is clear that, *applying the type of maneuvering indicated in the preceding section,* conditions near to these will be realized when the directions of maximum utilization of the ships are not inclined in a sensibly different way. We may conclude from this that, *in general, when the adversaries present to each other sides of opposite names, the rotation of their joining line may be held to be very slow.*

When, on the other hand, the two adversaries present to each other sides of the same name, the rotation of the joining line is very rapid; thus, supposing A and B to be distant from each other 9000 meters, that they have each other bearing at 45° from the beam, and that $V_A = V_B = 15$ knots, the time necessary to rotate the joining line through 90° is only 23 minutes. However, for the case in which, by presenting to the fire the side of the same name as that of the enemy, we may expose ourselves to having a rotation of the joining line in a direction contrary to that desired, let us see how the rotation can be obtained by presenting the side of the opposite name.

It is clear that, in order to have the maximum component of the speed normal to the joining line, it is necessary to maintain the maximum speed instead of reducing it according to the cri-

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tance, the line $O'_A O'_B$ should at all times be parallel to the joining line AB. But, considering the positions A' and B' of the two ships after the time dt, $O'_A O'_B$ should also be parallel to $A'B'$, and hence we should fall into an absurdity. In order to avoid this we must admit the coincidence above mentioned. (Author's note.)

terion given in the preceding section; and it is expedient to have the enemy bearing as near as possible to the beam, or, in one of the pre-established limit directions OM', OM'', of Fig. 22. If with the sight vane in one of these directions the distance changes, we continue to steer in this way up to the limit established for the distance, and then steer in the symmetrical direction with respect to the beam. So doing, by virtue of the aforementioned formula (10), the ship A sees the line joining it with the enemy incline itself in the direction in which the ship is moving, if there is realized the condition

$$V_A \sin \alpha > V_B \sin \theta.$$

When A has sufficient speed to permit the existence of this inequality, it is best to recognize that the above-mentioned maneuver is suitable only when a rotation of moderate amplitude is required. In fact, if $V = 18$ knots, supposing the bearing on which A steers to be such as to keep the distance constant, r, θ, and V_B being the same as in the example previously considered, two hours are required in order to rotate the joining line through 90°; but it may be observed that, to make the joining line rotate through 270°, by presenting to fire the side of the same name as that of the enemy, the necessary time would be $\frac{270}{90} \times 23$ minutes, or a little more than half the time above mentioned. Hence, for rotations of great amplitude, *avoiding the inconveniences of keeping the enemy bearing too near the beam and gaining in celerity, it would be advisable to produce the complement in* 360° *of the required rotation.*

We may then establish:

1st. In order to maintain an advantageous position with respect to the sun, to the coast, or to the strategic objectives, we must present to fire the side of a name opposite that of the enemy, applying the general type of maneuvering indicated in the preceding section.

2d. We must present to fire the side of the same name as that of the enemy, applying the general type of maneuvering, when in that way the rotation of the joining line takes place in the desired direction, or when the amplitude of the desired rotation is very great.

3d. If in presenting the side of the same name as that of the enemy the rotation takes place in the direction contrary to that

desired, if, furthermore, the desired rotation is of small amplitude and we have a speed superior to that of the enemy, it is well to present the side of the opposite name, maneuvering by the rules just pointed out. When, however, we have not sufficient speed for obtaining the object established, it is necessary to maneuver as has been said in the preceding case.

It results from the foregoing that it may be easier to maintain an advantageous position than to acquire it. In general we can have but little faith in being able to apply the second of the preceding deductions, for it is presumable that the enemy, when he sees our ship present the side of the same name as his own, may change the maneuver by exposing his other side if he deems it to his interest to avoid a rapid rotation of the joining line. Still, the contrary might happen when, for example, the enemy has commenced firing before we have done so, and does not wish to change the side, in order to avoid the disadvantage to the fire control that would be produced.

Evidently it would be a fine game if the enemy were obliged to present a determined side, as would be realized if his offensive field were unsymmetrical with respect to the longitudinal axis.

42. *Change of Distance.*—I. It is clear that in order to obtain a change of distance without sacrificing offensive power, a ship *A* must develop the maximum speed and keep the enemy bearing at the forward limit of a sector of maximum offense if he desires to diminish the distance, or at the after limit if he desires to increase it. The enemy *B*, in order to maneuver by the same standard, hindering the change, must keep *A* bearing respectively at the after limit, or at the forward limit of a sector of maximum offense.

By the fundamental relation, the ship *A* may impose a change of the distance when

$$V_A \cos \alpha > V_B \cos \theta;$$

α and θ corresponding in this case to the limits of the sectors of maximum offense.

II. Let us now suppose that the two adversaries are at the limit of offensive contact. The object of the ship *A* is to engage in a decisive combat with the ship *B*, which, not being able to prevent the approach of *A*, proposes to limit the action to the maximum distances. It is easy to see that if the ship *B* is powerfully armed on the line of the keel (has powerful head and stern fire), it may

be interested in keeping the stern always toward the enemy. In fact, if A, steering by sight vane, keeps B at the forward limit of a sector of maximum offense, calling this bearing α—counted, as usual, from the bow—by the fundamental relation (wherein we must, in this case, put $\theta=0$) it results that the necessary condition to the end that the distance may not increase, is

$$\frac{V_A}{V_B} \geqq \frac{1}{\cos \alpha}.$$

Consequently, the minimum speed necessary for A, in order to develop against the enemy the maximum power without falling out of range, is that corresponding to the greatest amplitude of the sectors of maximum offense; or it is determined by the relation

$$\frac{V_A}{V_B} = \frac{1}{\cos 30^\circ} = 1.15.$$

Putting $\Delta = V_A - V_B$, we have

$$\frac{V_A}{V_B} = 1 + \frac{\Delta}{V_B},$$

or

$$\Delta = 0.15\, V_B.$$

Hence it results that the superiority in speed required by A is so much the greater, the greater is V_B; or, while a greater speed per hour of 1.5 knots is necessary for the object mentioned against a ship of 10 knots speed, when $V=20$ knots, there is required an advantage of 3 knots.

This said, the following observations should be made:

1st. The aforesaid advantage in speed simply permits the ship A to keep B under the fire of his guns, but does not admit of his diminishing the distance.

2d. As has been pointed out in Part I, Chapter I, some ships can develop a strong intensity of fire in the direction of the keel—much greater than that of which they are capable in the sectors of minimum offense; moreover, it is well to remember (Section 3) that, at the maximum fighting distances, a ship presenting itself end on to the enemy's fire diminishes in that way the enemy's percentage of effective hits.

3d. It is true that, being removed by a small angle from the direction of the keel, one enters a sector of minimum offense; but this may also happen for the limit direction of the sector of

maximum offense on which A is steering; in other words, if A desires to provide against the inexactness of steering by sight vane, rather than at 30° from the bow, it ought to keep the enemy at about 35°; but then, for $V=20$ knots, there would be required an advantage in speed of 4.4 knots, rather than of 3 knots. It seems, then, that we may affirm that, even supposing the sectors of maximum offense to have the maximum amplitude, without a great advantage in speed, not presumable in practice, the situation is not very decidedly favorable for A. On the other hand it appears to be clear that B *may not be interested, in this case, in conforming to the general rule, which is that of keeping the enemy bearing in a sector of maximum offense.*

If the ship A, then, has not a speed which greatly exceeds that of B, his desire to succeed in the intention to diminish the distance constrains him to keep his bow toward the enemy; which obliges him to endure, for a very considerable time, a disadvantageous situation, when the strength of his fire in line with the keel is inferior to that of the enemy. In fact, it is sufficient to note that, in order to diminish the distance by at least 2000 meters—which it is important for A to do in order to engage in a quickly efficacious action—the necessary time is that which would be required for passing over the said space at a speed $V_A - V_B$; or, it is more than 20 minutes if the difference in speed is about 3 knots.

When, however, the ship A, besides being the swifter, has also a more powerful fire in line with the keel, it is clear that B will be obliged to bring it to bear in a sector of maximum offense; we then come back to the case already discussed at the beginning of this section.

In the general case of two ships opposed to each other on the open sea, we may then conclude:

1st. That, for declining a decisive tactical action, powerful stern fire may constitute a compensation for inferior speed.

2d. That a speed superior by two or three knots, even if associated with the maximum amplitude of the sectors of maximum offense, cannot be held to be sufficient for imposing the tactical action; powerful fire ahead is more important for securing that object.

43. *Capacity for Tactical Initiative.*—A ship has complete liberty of tactical initiative with respect to another if it can

impose or decline offensive contact; and if, in case it engages, it can give to the action the form that is deemed preferable, or can control its development.

After what we have said, it is easy to estimate in what degree such liberty is possessed; that is, to determine the elements of the *capacity for tactical initiative* with reference to the usual hypothesis of ships opposing each other on the open sea.

I. In the general case in which the distance at which the ships sight each other is beyond the limit of offensive contact, equality of speed is sufficient for avoiding said contact, while, to impose it, a superior speed is necessary.

II. For the slower ship, the capacity for limiting the offensive contact to the maximum distance is inversely as the capacity of the faster ship to impose a decisive combat; in practice, they depend essentially upon the relative potentiality of the two adversaries in fire in line with the keel.

III. As between two ships that keep each other bearing in sectors of maximum offense, the capacity for controlling the distance depends upon the relative conditions of maximum speed and of amplitude of the sectors of maximum offense; these two factors should be considered together for each combatant; or, a compromise between them is possible. Indeed, as is seen from the fundamental relation, the aptitude of a ship to control the distance depends upon the product of its speed by the cosine of the angle formed by the longitudinal axis with a limit direction of the sector of maximum offense. If the forward limit direction of this sector forms with the direction of the bow a certain angle, $\alpha-\mu$, this places the ship in the condition in which it would be found if the limit direction formed the angle α, but the maximum speed V had an increment, kV, k being a coefficient that renders

$$V\cos(\alpha-\mu)=(V+kV)\cos\alpha;$$

hence we have

$$k=\frac{\cos(\alpha-\mu)}{\cos\alpha}-1.$$

If we were considering the after limit direction of the sector of maximum offense it would be necessary to put $180°-\alpha$ in place of α, and $180°-\alpha+\mu$ instead of $\alpha-\mu$; hence the formula found for k is a general one.

In the three hypotheses (Section 2) of sectors of maximum offense extended to 30°, 45°, and 60° from the beam, the values

of k for $\mu=5°$ are respectively 0.14, 0.08, 0.04. For $\mu=10°$ the values of k just given are doubled; that is, k may be held to be proportional to μ. For the ordinary case in which the two ships have sectors of maximum offense with amplitude near to 45° forward of and abaft the beam, it is then to be remembered that *if a ship has, with respect to another, the limits of the sectors of maximum offense nearer to the longitudinal axis, every 5° of difference of this kind, or every 10° of advantage in the total amplitude of the sectors, is equivalent, in the particular regard now under discussion, to an increase of speed of 8/10 of a knot for every 10 knots.*

IV. Generally the maneuvering of a ship in the duel is developed by keeping the adversary in one of the four fractions of the sectors of maximum offense; as, SOM'', $S'OM'$ of Fig. 22, included between the limit directions of said sectors and the directions nearest the beam to which corresponds a sufficient defensive capacity; *the wider these partial sectors are, the greater is the liberty of maneuvering.* From this comes the superiority that is derived from greater thicknesses of armor than those of the enemy, or from guns with greater penetrating power.

V. To the end that a ship may be able to impose the rotation of the line joining it with the enemy, it must be able to obtain, with respect to the enemy, a greater component of its speed normally to the said joining line. This depends upon the relative speed conditions and upon the angles that, for each ship, the directions OM'', OM' of Fig. 22 form with the beam. *In this particular respect an advantage in speed is hence equivalent to a greater thickness of armor or to a greater penetrating power of the guns.*

From the preceding observations it results that the importance of the various elements of the capacity for tactical initiative cannot be considered in a one-sided manner.

It is incontrovertible, then, that the said capacity increases with the amplitude of the sectors of maximum offense; but with this amplitude (Section 3), the ratio between the potentiality in line with the keel and that of the said sectors diminishes; nor, on the other hand, can an increase of the said amplitude render an advantage in speed less desirable. This deduction is to be borne in mind when considering the types of ships.

44. *Maneuvering at Close Range.*—Let us examine the manner in which maneuvering at close range may be developed; that is to say, within the limits of the fourth tactical zone distinguished in Section 24, when the employment of the torpedo is possible, and hence, from what we demonstrated in Section 9, it is preferable to have the enemy bearing abaft the beam.

It must be borne in mind (Section 3) that the probability of being hit by the guns at close range, while it remains constant if the direction in which the enemy bears is not removed more than 45° from the beam, rapidly increases beyond that limit; therefore it is not advisable to have the enemy bear more than 45° from the beam, or, it is not advisable to utilize a greater amplitude of the sectors of maximum offense.

In maneuvering at close range, then, we should generally have the enemy bearing in a direction of maximum utilization abaft the beam, and should present to fire the side of a name opposite that of the enemy; because in that way it is possible to steer by sight vane (Section 37), which permits of satisfying the tactical necessities in a continuous manner.

If the enemy has our ship bearing forward of the beam, it is well to develop the maximum speed or a speed somewhat inferior —as has been said for maneuvering at long range—with the intention of keeping the enemy at the desired distance. For some moments we may change the angle of the sight vane when this may be necessary in order to launch the torpedoes; we must not, however, forget the risks we run in presenting the beam at close range; and hence it is necessary to establish it as a rule, not to execute, within the limits to which we are referring, any passage from a bearing abaft the beam to one forward of the beam, or vice versa. In consequence of this, except in the case to which we shall now allude, the launching tubes of the forward sectors should be utilized by launching for an angled run.

It is clear that if the enemy maneuvers analogously, keeping our ship bearing abaft the beam, neither of the combatants is within the radius of action of the torpedo; the duel then remains an artillery battle exclusively.

Let us consider the situation of two adversaries that, at close range, have each other bearing forward of the beam.

The distance diminishes; the ship that, at a certain moment, in order to avoid a further diminution of the distance, brings the

enemy to bear abaft the beam, while the enemy continues to keep it forward of the beam, presents the beam during the change, and hence makes—as has been said before—a perilous maneuver.

If neither of the adversaries makes such a maneuver, and if they present to fire sides of opposite names, they come to close quarters.

When the sides exposed to fire are of the same name, if one of the adversaries desires to fight at close quarters, the other cannot avoid it; let us suppose that this is not desired by either of the combatants. They keep the course constant; and, if the courses are parallel, the polar bearings are the same at any moment. *Thus, passing on opposite courses, inasmuch as it leads the two adversaries to present the beam simultaneously, may seem an opportune form of maneuvering for two combatants, both desirous of using the torpedo.* However, it is to be noted that only in appearance are the combatants in identical conditions; *the more strongly armored ship acquires the advantage,* owing to the fact that the adversary abandons maneuvering on the bearing which would permit him to compensate for, or at least diminish, the greater vulnerability of his armor.

Under the hypothesis that the enemy has our ship bearing forward of the beam, we may then conclude:

1st. It is not necessary to have the enemy bearing forward of the beam at close range, unless we intend to provoke a battle at close quarters, or unless we have decided to undergo it.

2d. Not desiring battle at close quarters, the maneuver of having the enemy forward of the beam may be rational when our ship has side armor of greater thickness.

45. *Limit of Battle at Close Quarters.*—Below a certain distance from the enemy, a ship may be assured that, if a collision takes place, it may run into the other, instead of being itself run into.

Theoretically, when we have the greater speed, we run no risk in having abaft the beam an enemy who has us forward of the beam; but it is necessary to take unforeseen elements into account, and hence the necessity of not having the enemy abaft the beam below a certain distance, determined under the hypothesis of equal speeds and equal evolutionary qualities for the two combatants. This distance marks *the limit of battle at close quarters.*

Let us consider two ships, A and B (Fig. 25), that have each other bearing respectively the one astern and the other ahead, and that have the same speed, V. Let us hold their evolutionary curves to be circular. We must seek the maximum distance, AB, which will permit A to arrive at K' at the same time as B.

Let us admit that the arcs BK and MK' are passed over in the same time—which is not rigorously true, since one is described

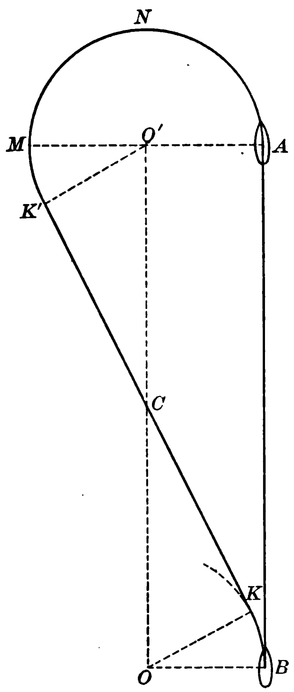

FIG. 25.

at the beginning, and the other at the end of an evolution. KK' must be passed over in the time that A takes in passing over the semi-circumference ANM.

Indicating by ρ the radius of the circle of evolution, since A loses about one-third of his speed, we have

$$\frac{KK'}{V} = \frac{\pi\rho}{\frac{2}{3}V},$$

or

$$KK' = \tfrac{3}{2}\pi\rho.$$

Since $AB=2CO'=2\sqrt{O'K'^2+CK'^2}=2\sqrt{\rho^2+\frac{1}{4}KK'^2}$, substituting for KK' its value, we obtain

$$AB=\rho\sqrt{4+\tfrac{9}{4}\pi^2}=5\rho \text{ (about)}.$$

On the basis of the values that we may attribute to ρ, and considering that the value found for AB refers to the extreme case wherein A has the enemy bearing exactly astern, we may hold the distance of 2000 meters to be the limit of battle at close quarters.

46. *Maneuvering at Close Quarters.*—Battle at close quarters has lost the importance that it had in the past when it was held to be the principal form of action; for this reason we shall confine ourselves to brief considerations.

The ramming maneuver against a ship with freedom of movement is extremely hazardous. Indeed, the instant at which a ship must reach the intersection of its track with that of the enemy in order to obtain the object of ramming him, differs very little from that at which the said ship would be itself rammed. For this reason, and owing to the fact that modern ships have in the gun and in the torpedo most powerful means of fighting, it is to be admitted that neither of the adversaries is likely to maneuver with ramming as the principal objective.

In maneuvering at close quarters we must nevertheless take into account the possibilities of ramming; that is to say, we must maneuver so as to avoid being rammed. In other words, it is necessary to maneuver *defensively* with respect to ramming.

The *offensive* maneuver for ramming would require having the bow directly toward the enemy; for this reason, when the tactics of the ram were a subject of study, it was admitted that the two combatants would have steered initially bow against bow; but, afterwards, considering that such a direct clash would have placed both the adversaries in identically disadvantageous conditions (no matter how different might be their structures), it was held by the majority of the authors that the two ships would have turned aside little by little. As a collision at a small angle is dangerous for the rammer as well as for the rammed, it was also admitted that the two ships, in order to avoid it, would both have turned aside with the same helm, thus changing the collision into a grazing, or slipping past at short distance; after which they would have executed offensive turns with intent to ram.

For the *defensive* maneuver with respect to ramming, it is not necessary—as it is for the *offensive* maneuver—to tend to keep the enemy at an angle from the bow less than that at which he keeps us, but it is sufficient that the two bearings be equal. On the basis of this consideration, the form that it seems the initial phase of battle at close quarters between two modern battleships should assume, is not exactly that which appeared probable in the tactics of the ram. Within the limit of distance indicated in the preceding section, the two ships will run to meet each other; but, instead of steering bow to bow, they will keep on their guard, following parallel courses; there will thus be, not a grazing by, nor a passing at very short distance, but a passing at a distance of some hundreds of meters, such as to permit making use of the guns and the torpedoes.

After passing by, and before the enemy gets out of the after sector of maximum offense, it is evidently logical to turn in order to keep him in that sector; therefore the two ships will turn at that time toward each other; and afterwards, for the same reason, they will change course again, thus following parallel broken straight lines, having each other bearing abaft the beam; and hence, they will draw away from each other. Given—but not conceded—that the passing by may not have had the gravest effects, if one of the ships desires to provoke a repetition of the preceding phase, it will have to turn toward the enemy in order to bring him to bear about 45° forward of the beam; the other ship will be obliged to turn also in the same way.

It is to be noted that while admitting it to be unlikely that one of the ships will maneuver, after the passing by, in order to ram, the other—unless his mobile and evolutionary qualities are greatly inferior—by turning with the helm hard over, will be in time to present his bow to the adversary. Hence we deem rational the opinion of to-day favoring the abolition of the ram.

47. *Particular Cases.*—In practice—as was said at the beginning of this chapter—particular circumstances will determine the form that the duel will assume.

Ordinarily one of the adversaries will be sensibly weaker than the other, and will seek to reach a movable or a fixed center of protection. Hence it is possible that the enemy may or may not be found between the center of protection and the ship that desires to decline battle.

In the second case the weaker ship will evidently have to run; and will place itself in safety if it has an advantage in speed, or if its inferiority in speed is not too great, and if the radius of action in which the said ship must operate has been conveniently established, taking into account the speed of the enemy's strongest ships.

In case, however, it is indispensable to reckon with the enemy in order directly to reach the center of protection, the weaker ship could run away if it had an advantage in speed, and seek to throw the enemy off its track; but when it is feared that in this way the ship may run into preponderating hostile forces, it will steer directly for the center of protection, thus coming into a fight at close quarters with the enemy.

This is the case in which encounters between torpedo boats very often take place, especially during blockading operations, as has been demonstrated in the Russo-Japanese war. The destroyers and torpedo boats of the defense, having come out during the night in search of the enemy's battleships, returning at daylight toward their base, may encounter on their route similar units of the enemy; and as, for the said vessels, running to seaward would signify exposing themselves to certain loss, they will be obliged to fight. The adversaries will steer for each other bow to bow, so that the fight will first be developed in line with the keel, and afterwards, by passing each other on opposite courses, at very close quarters. After this, the units of the blockading party, unless they have sustained injuries that impede their freedom of maneuvering, will invert the course, following the enemy to the vicinity of the base.

Between protected cruisers, when the weaker is the slower, and has not a potentiality of fire in line with the keel that is sufficient for maneuvering by the rule given in Section 42, or when for any reason it cannot avoid a decisive action, it will seek to escape from the bad situation by provoking battle at close range. The stronger ship will evidently be interested in keeping the enemy at a distance.

CHAPTER III.

TACTICAL EVOLUTIONS.

48. *Tactical Evolutions and Maneuvers.*—Let us consider a compact fleet with the units grouped in the manner deemed to be expedient for tactical action, and at the distance from each other which is established as the normal.

In contact out of range the objective of the movements may be that of delaying offensive contact, or of taking a determined position with respect to the enemy, arriving at offensive contact with an advantageous alignment. In general the tracks must be rectilinear. At intervals of time it may be necessary to execute changes of course or of alignment; that is to say, to perform evolutions; the fleet may then be ordered with the maximum exactness, and the control may be completely exercised by means of signals.

In offensive contact we find ourselves under conditions different from those just indicated; we ought to have *at every moment* an opportune alignment and a suitable inclination of the ships to it; therefore, in general (as has already been pointed out in section 17), an immediate and continuous adaptation of the proper maneuver to that of the enemy is desirable. Limited confidence can be placed in signals, because, aside from other things, they require for their transmission a time that is not inconsiderable, even when use is made of repeating vessels not stationed in the line. In order not to be surprised and disconcerted, it is then necessary to be prepared to maneuver on the basis of simple *directives*—each division imitating the movements of the one immediately under the orders of the commander-in-chief; and, analogously, the single ships of each division regulating themselves by the one among them that is charged with the conduct of the maneuver.

We must, then, necessarily admit that the evolutions cannot, in general, satisfy the necessities of offensive contact, reflecting (as already results from section 33) that they ordinarily require two changes of course of considerable amplitude, which disturbs the firing; moreover, when an evolution is ordered, it is necessary to

foresee what will be the tactical situation at its end, or, after a time that is notably long, when the naval force is numerous. Such a length requires the prevision alluded to, and, on the other hand, renders it very difficult—the enemy being free to maneuver according to his desire. It is to be observed that, naturally, this prevision is also necessary when an evolution is ordered in contact out of range; however, if in the course of the evolution we do not arrive at offensive contact, we may, at least in part, nullify the effects of an erroneous prevision, by so regulating ourselves as to delay the approach. Finally for the duration of the evolution, the movements of the single units are restricted; and it is clear that this restriction cannot permit the best employment of the weapons and satisfy the variability of the tactical situation. Let us, then, admit the principle that *in contact out of range we perform evolutions, and in offensive contact we maneuver; having, in the latter case, as little recourse to evolutions as possible.*

Definitions.—We shall call *tactical evolutions* those proper for the government of a fleet in contact out of range, thus distinguishing them from the multiplex evolutions that can be imagined.

Under the name of *tactical maneuvers* we shall include those maneuvers that are required for the control of a fleet in offensive contact.

In this chapter we shall study tactical evolutions, considering successively the hypotheses that the fleet may have a simple alignment and a double alignment. We shall subsequently refer to the case of separated groups in contact out of range.

49. *Evolutionary Speed—Reserve of Speed.*—As is well known, to the end that a ship may keep in the formation it is necessary for it to have a *reserve of speed;* or, the *normal speed* must be somewhat inferior to the maximum speed of the slowest unit. On the other hand, in order to render the evolution as rapid as possible, it seems to us well to establish that, as a general rule, the evolutionary speed shall always be equal to the said maximum speed of the slowest unit. Consequently, when, for instance, we say that *the evolution is performed with the speed ratio of* $\frac{1}{2}$, it is established that the pivot ship reduces its speed, not to one-half of the normal speed, but to one-half of the evolutionary speed.

The minimum reserve of speed that each ship in the formation should have at its disposition must be a fraction determined by the normal speed; or, it must be of greater value the higher is the

normal speed; in fact, a ship that is not exactly on the desired line of bearing, in order to get into position, determines *by eye* the small change of course necessary; but, as equation (3) of Chapter I shows, the amplitude of the change of course—and hence the time required to get into the formation—depends upon the ratio between the normal speed and the evolutionary speed, and not upon their difference. Let us admit that the minimum reserve of speed may be defined by the ratio

$$\frac{\text{normal speed}}{\text{evolutionary speed}} = \tfrac{9}{10}.$$

50. *Evolutions to be Considered for a Simple Alignment.*—In relation to what we established in section 18, let us consider a naval force composed of two elementary alignments, each of which does not contain more than six ships. Let the naval force be upon a single line of bearing.

As we said in section 12, the formation has of itself no importance. Having admitted this idea to be fundamental for offensive contact, we ought to take it *a fortiori* as a guide in the study of contact out of range. In the latter, given the objects that we may decide upon, the first element to be determined in relation to them is the course; when the alignment is adjudged to be satisfactory, or when a change of course is urgent, such change is made simultaneously.

This said, let us suppose that the fleet has the proper course, which we will call the *advantageous course,* and that it is desired to change the alignment. The evolution to be performed consists in a change of polar bearing, which may be executed by one of the following methods:

1st. By changing course in succession (contromarcia).

2d. By oblique courses.

3d. By methods based upon the wheeling of the single column.

51. *Change of Course in Succession.*—In order to satisfy tactical necessities, from among the ways in which this method may be applied, we should select the one *that permits of losing the least distance in the direction of the advantageous course.*

The problem being thus set forth, it results therefrom that the transitory courses during the evolution should not make with the advantageous course an angle greater than 90°.

Let $A_1 \ldots . A_n$ (Fig. 26) be a line of polar bearing α. A_1Z being the initial course—which we will suppose to be the advan-

tageous course—the transitory course must be included in the semicircle X_1ZX_2, X_1X_2 being normal to A_1Z. Desiring, then, to assume an alignment Y_1Y_2, it is to be observed: 1st, that it is not well to execute the evolution ***in inverse order;*** that is to say, by changing course simultaneously in the direction A_1A_n, which is without the said semicircle; 2d, that, for the same reason, in the evolution in direct order, that is, changing course simultaneously in the direction A_nA_1, it is not well, after such change, to execute the change in succession in the direction A_1Y_1, although the angle TA_1Y_1 is smaller than TA_1Y_2.

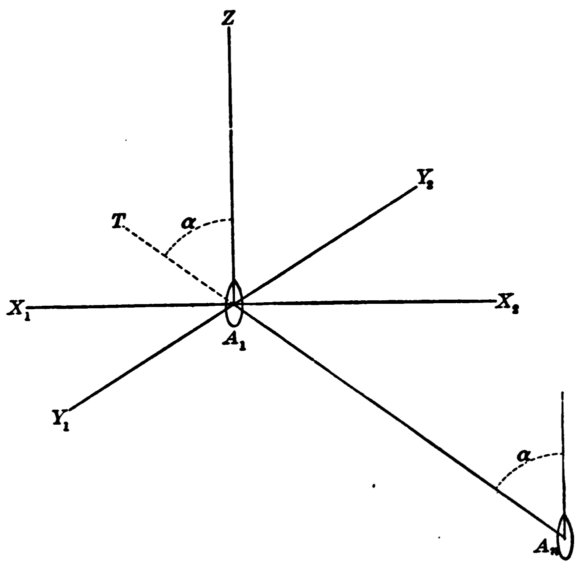

FIG. 26.

The rules for the evolution are hence the following:

1st. The ships change course simultaneously through the angle toward the ship farthest advanced in the direction of the advantageous course, resulting thus in a column of vessels.

2d. The leading ship, followed in succession by the other ships, changes course in the direction of the new alignment which makes the minimum angle with the advantageous course.

3d. When the last ship has completed the turn in the wake of the leading ship, the ships change simultaneously to the advantageous course.

It is to be noted that the change of course in succession, which constitutes the second part of the evolution just described, can be executed at evolutionary speed rather than at normal speed, because a ship that may have fallen slightly behind may put itself exactly in position by not following exactly in the wake of the one that precedes it, when it makes the turn.

52. *Oblique Courses.*—With the method by oblique courses, as has already been said in section 33, the extreme ship toward which the alignment inclines, reduces its speed, and the ships change course through an angle given by an appropriate table. If the angle of the change of course were estimated by each ship, that is to say, if it were not sought to determine it with the aid of a table or an instrument, it could only result in the employment of a longer time for the evolution, without any gain in simplicity.

The angle of the change of course could be determined as indicated by Admiral Morin in his profound work entitled *Degli ordini e delle evoluzioni di' un' armata* (*Rivista Marittima,* 1873-1874) ; but even in that case the evolution would not be completed in the minimum time.

It might also be prescribed that the intermediate ships of the formation should regulate their speed so as to arrive simultaneously on the new alignment; but the reasons for so doing are insufficient, while, on the contrary, for the case in which it is necessary to confront an unforeseen situation, it is preferable that each ship should arrive on the new alignment as soon as possible, as was proposed by De Gueydon.

The maximum value of the speed ratio that can be adopted in evolutions must be inferior to the value $\frac{9}{10}$ established in section 49; that is to say $\frac{8}{10}$. On the other hand, as we have already said in Chapter I, the minimum value that can be adopted for this ratio is $\frac{1}{2}$.

This being the case, it seems logical to perform evolutions with the ratio $\frac{1}{2}$ when the rapidity of the evolution is principally required, and adopt the ratio $\frac{8}{10}$ if rapidity must be sacrificed to the condition of losing the least distance possible in the direction of the advantageous course; it is well, however, to make a few reflections in this connection.

Let us indicate by V_A the evolutionary speed, and by V_B the speed of the pivot ship. Let t' and t'' be respectively the times

employed in a change of bearing of an amplitude ω with the values $\frac{1}{2}$ and $\frac{8}{10}$ for $\frac{V_B}{V_A}$. By formula (6) of Chapter I we have:

$$\frac{t''}{t'} = \frac{V_r'}{V_r''}. \qquad (1)$$

V_r' and V_r'' being the relative speeds corresponding to t' and t'' that are deduced by the formula in section 31, which gives V_r; this formula can be written:

$$V_r = V_A\sqrt{1+\left(\frac{V_B}{V_A}\right)^2 - 2\frac{V_B}{V_A}\cos\delta},$$

in which δ is the angle of the change of course given by equation (3) of Chapter I as a function of $\frac{V_B}{V_A}$ and $\beta_1 - \frac{\omega}{2}$; β_1 being the polar bearing on which the ships are found with respect to the pivot ship at the beginning of the evolution.

In the time t'' necessary for the evolution with the ratio $\frac{8}{10}$ the space passed over by the pivot ship, which we will indicate by p'', is given by

$$p'' = 0.8\,V_A t''.$$

Let us bear in mind that $\frac{9}{10}V_A$ is the normal speed; consequently, if the evolution is performed with the ratio $\frac{1}{2}$, the track p' of the pivot ship in the time t'' is evidently

$$p' = 0.5\,V_A t' + 0.9\,V_A(t'' - t');$$

and hence we have

$$p'' - p' = \left(0.4 - 0.1\frac{t''}{t'}\right)V_A t'. \qquad (2)$$

Let us indicate the ratio $\frac{p''-p'}{V_A t'}$ by u; the values of $\frac{t''}{t'}$ calculated with formula (1), and those of u, which are obtained by means of (2), are assembled in the following table in which $\beta_1 - \frac{\omega}{2}$ is made to vary from 0° to 90°, bearing in mind that with supplementary values of $\beta_1 - \frac{\omega}{2}$, formula (3) of Chapter I gives values of δ that are equal, but with the contrary sign; and hence the same V_r corresponds thereto.

$\beta_1 - \frac{\omega}{2}$	$\frac{t''}{t'}$	u
0°	1.4	0.26
30°	2.0	0.20
60°	2.4	0.16
90°	2.5	0.15

These values show that if $\beta_1 - \frac{\omega}{2}$ is included between 30° and $180^\circ - 30^\circ = 150^\circ$, and if the evolution is such that it is of long duration when executed with the speed ratio $\frac{1}{2}$, the advisability of the evolution with the ratio $\frac{8}{10}$ is to be excluded, because the greater distance gained in the direction of the course appears to be a negligible advantage when compared with the increase that is realized in the duration of the evolution; in other words, the time necessary for securing the benefit represented by the difference $p'' - p'$ is so long that we cannot rely upon the tactical conditions remaining stationary long enough to permit of completing the evolution.

For example, let us suppose the speed $V = 18$ knots an hour, or 558 meters a minute; let $\beta_1 - \frac{}{2} = 75^\circ$ and $t' = 10$ minutes, as is the case with a fleet of ships in line abreast at intervals of 500 meters, that wishes to change the bearing through 30°; we have, then, $t'' = 24$ minutes (about), and $p'' - p' = 0.16 \times 558 \times 10 = 890$ meters.

If $\beta_1 - \frac{\omega}{2}$ is less than 30° or greater than 150°, the angle of change δ is greater than that which would be required, for the same value of ω, in the case before considered; that is to say, with respect to that case, and with the same method, the evolution is more rapid; and it is to be noted that t'' diminishes more rapidly than t' because, as the table shows, the ratio $\frac{t''}{t'}$ diminishes while u increases; and hence the evolution with the ratio $\frac{8}{10}$ may really be advantageous. For example, for the fleet of 12 ships before supposed, when $\beta_1 = 40^\circ$ and $\omega = 30^\circ$, we have $t' = 7.5$ or $t'' = 12$ minutes, and $p'' - p' = 0.22 \times 558 \times 7.5 = 940$ meters.

Now let us note that in order to have $\beta_1 - \frac{\omega}{2} < 30^\circ$, it is necessary for β_1 to be between $\frac{\omega}{2}$ and $30^\circ + \frac{\omega}{2}$; but since, as a measure of safety, we cannot allow the course of the pivot ship to be crossed during the evolution, β_1 must be included between ω and $30^\circ + \frac{\omega}{2}$; or, it must be greater than $150^\circ + \frac{\omega}{2}$.

Moreover, considering that it is necessary to avoid excessively long evolutions, it is well that the evolutions with the speed ratio

$\frac{8}{10}$ should be restricted to the case in which ω is not greater than 30°; so that such evolutions, in view of the limits of β_1 just found, may be deemed advantageous *for lines of bearing nearer to the column of vessels than to the line abreast.*

When ω does not exceed about 10°, t' is small whatever may be the value of $\beta_1 - \frac{\omega}{2}$, and hence no importance can be attributed to the difference $p'' - p'$; however, as t'' is also sufficiently small, the evolution with the ratio $\frac{8}{10}$ is justified by the possibility of obtaining the object *with the minimum alteration of course and speed.* In other words, we may in general affirm the propriety of adopting the ratio $\frac{8}{10}$ when the evolution can almost be considered as a rectification of the formation. It is clear that in such case it is not advisable to apply the rule of De Gueydon for the change of course of the pivot ship; the course of the pivot must remain unchanged.

The evolution with the ratio $\frac{1}{2}$ is then advisable when ω is of considerable amplitude, and the formation is nearer to line abreast than to column of vessels.

53. *Change of Alignment by Wheeling.*—I. Admiral Bouet de Willaumez, in his *Projet de tactique navale* (1855), in which he laid down the basis for the evolutionary systems for steam vessels, in considering the wheeling of a fleet drawn up in line abreast, alluded to the system of pivoting on the center ship, one-half of the vessels going ahead and the other half backing; naturally, he discarded the method, since evolutions cannot be performed by going astern, and he limited the practical methods to those which pivot on one of the extremities of the formation. Nevertheless, the idea of the illustrious admiral can be applied to the wheeling of a column of vessels without need of backing the engines; in such case, as indicated by the anonymous writer in the United Service Magazine already cited (section 33, III), it is possible to change the alignment by pivoting on an intermediate ship of the formation; or, the line may be considered as composed of two parts, one of which has the pivot ship for a leader, and the other has it for the rear ship; and hence the first performs the evolution by executing the wheel on the leading ship, while the other makes the change of course necessary for wheeling on the rear ship.

On the basis of the idea already advanced that, tactically, it is not important to maintain a fixed formation, we may not, in gen-

eral, assign importance to wheelings; that is to say, it is not necessary at the end of the evolution to re-establish the polar bearing that the formation had initially; however, if the wheeling of a column of vessels can be executed rapidly by pivoting on an intermediate ship, we are induced to favor this method for changing an alignment, considering the column of vessels as a transitory formation, as is done in evolutions performed in succession. In other words, being upon any line of polar bearing α, in order to change the alignment we can change the course of the ships simultaneously through the angle α, thus bringing them into column of vessels, then execute the wheel on a conveniently selected pivot ship, and afterwards, with another simultaneous change of course, take the direction that is deemed advantageous.

In such an evolution the pivot ship evidently cannot maneuver according to the rule of De Gueydon, because the two parts of the line execute changes of course in contrary directions; hence, the pivot ship must alter the course through the angle ω, through which it is desired to change the alignment, and afterwards reduce speed in the desired ratio with the evolutionary speed.

After what has been said in section 33, it is easy to determine the criterion according to which the pivot ship should be selected.

Evidently, in order to wheel a column of vessels A_1A_2 (Fig. 18), the ship B most convenient as a pivot, is the one to which there corresponds an evolution of the same duration for each of the extreme ships, A_1 and A_2, that are respectively the rear ship and the leading ship. Having demonstrated that $\frac{A_1B}{A_2B} > 1$, it quickly follows that *the point of rotation is ahead of the center of the line.*

In particular, from the table of section 33, IV, which, for the speed ratio $\frac{1}{2}$, gives the values of the ratio $\frac{t_2}{t_1}$ between the duration of a wheel on the rear ship, and that of a wheel on the leading ship (or, it gives the values of $\frac{A_1B}{A_2B}$), we may deduce the ratio $\frac{A_2B}{A_1A_2}$; that is, the distance of the pivot from the leading ship as a function of the length A_1A_2 of the line. In fact, we have

$$\frac{A_2B}{A_1A_2} = \frac{1}{1+\frac{A_1B}{A_2B}} = 1 + \frac{1}{1+\frac{t_2}{t_1}}.$$

Indicating by t_3 the duration of the wheel when pivoting on B, it is clear that $\frac{A_2B}{A_1A_2}$ is equal to the ratio $\frac{t_3}{t_2}$, the values of which, multiplied by the corresponding values of $\frac{t_2}{t_0}$ given by the table of section 33, IV (t_0 being the duration of the evolution performed in succession), give us those of the ratio $\frac{t_3}{t_0}$.

In the following table are set down the values of the two above-mentioned ratios.

ω		$\frac{t_3}{t_2}$	$\frac{t_3}{t_0}$
15°	....	0.46	0.15
30°	....	0.42	0.29
45°	....	0.39	0.43
60°	....	0.36	0.55
75°	....	0.33	0.65
90°	....	0.31	0.75

These results show: 1st. That with ω greater than 60° the pivot ship may be held to be the one at about one-third the length of the column from the leading ship; while, if ω is less, the pivot ship is the one at about four-tenths of that distance. 2d. That the method of wheeling just cited is advantageous when compared to that performed in succession, especially for values of ω less than 60°.

From what has been said, the ships astern of the pivot ship should change course as in any ordinary wheel on the leading ship; but, for a certain number z of them, the evolution may be simplified by prescribing that they follow the pivot ship in succession on the basis of the following considerations.

As the pivot ship, after having changed course through the angle ω, takes up the speed $\frac{1}{2}V_A$, a ship that occupies the position z astern of the pivot, and which follows it in succession, arrives on the new alignment after a time $z\frac{d}{\frac{1}{2}V_A}$; d being the distance between two adjacent ships.

To the end that the said time may not exceed that occupied by the last ship of the line in executing the wheel, it is necessary to realize

$$z\frac{d}{\frac{1}{2}V_A} \leqq t_3.$$

Let n be the total number of ships composing the line. The time that would be occupied in following the leading ship in succession at a speed V_A is expressed by

$$t_0 = \frac{(n-1)d}{V_A};$$

and hence we must have

$$z \leqq \frac{(n-1)}{2} \frac{t_s}{t_0},$$

in which the values of $\frac{t_s}{t_0}$ that it is necessary to introduce are those previously obtained. Under the two hypotheses of a line composed of 12 or of 8 units, the number of ships that can maneuver in succession astern of the pivot ship is given by the following table:

ω	$n=12$	$n=8$
15°	..	..
30°	1	1
45°	2	1
60°	3	1
75°	3	2
90°	4	2

So, as an illustration, with a line of 12 ships, wishing to execute a wheel of about 90°, the first four ships and the last three must perform the evolution at a speed V_A, while the five center ships must keep the speed $\frac{1}{2} V_A$.

In general, the difference of speed required for the center ship and for those at the extremities shows, as is noted by the English writer already mentioned, that this method of changing the alignment is *particularly advisable when the limited speed of the fleet is due to considerable differences in the maximum speeds of the various ships.* In fact, it has already been established that the normal speed must be $\frac{9}{10}$ of the maximum speed of the slowest unit; it has, furthermore, been affirmed that the evolutionary speed may be equal to the said maximum speed. This limit cannot be exceeded in evolutions performed in succession, and in those with oblique courses wherein one of the extremities of the formation is made the pivot, it being necessary that the angle of change of course be the same for all the ships. It is clear, however, that in order to obtain the maximum rapidity in wheeling the column of vessels by the method described, *if the divisions composed of the fastest ships are placed at the extremities,* such ships can avail

themselves, not only of the reserve of speed defined in section 49, but also that which results from the difference between the normal speed of the fleet and the maximum speed of the said divisions.

If the ratio between the maximum speed of the central division and the maximum speed of the extreme divisions does not exceed $\frac{8}{10}$, from what proceeds there results, within certain limits, *the possibility of wheeling the line without loss of speed to the fleet as a whole,* by executing the change of course ω in succession with the central division, and by the ships of the extreme divisions going to their positions with the reserve of speed. With the speed ratio $\frac{8}{10}$, this method may be held to be advisable when ω does not exceed 30°.

II. Let us suppose our fleet to be on any line of polar bearing α; let OS (Fig. 27) be the alignment, OR the course steered; and it

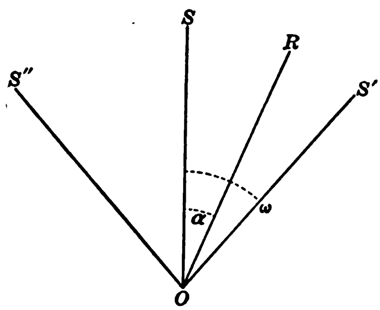

FIG. 27.

is desired to pass to the alignment OS', inclined to the present alignment at the angle ω, pivoting on one of the extreme ships. Analogously to what has previously been said, we can have recourse to the column of vessels as a transitory formation, by changing course together on the initial alignment, and then wheeling the column on the rear ship or on the leading ship, changing course in the first case through the angle ϕ_c in the direction of the new alignment, and in the second case through the angle ϕ_t in the contrary direction; ϕ_c and ϕ_t being the angles given by formula (4) and (5) of Chapter I. Let us observe, however, that the ships being, by hypothesis, already inclined by the angle α in the direction of the new alignment, the angle of change, instead of ϕ_c, is $\phi_c - \alpha$ in the case of pivoting on the rear, and $\alpha + \phi_t$ when pivoting on the head. Taking this into consideration, the evolution may

then be executed in the same manner indicated in Chapter I, for wheeling a column, without any complication whatever; because, according to the case, it suffices to subtract from, or add to, the angle of the change of course taken from the table for wheeling the column, the polar bearing of the formation.

It is obvious that the evolution is executed analogously if the new alignment is inclined the opposite way; thus, in Fig. 27, if the new alignment is OS'', the angle of change for wheeling on the rear ship is $\alpha+\phi_c$, and for wheeling on the leading ship it is $\alpha-\phi_t$.

Having thus generalized on the wheeling of the line, let us look into the importance to be attributed to such an evolution.

The party A (Fig. 28) has an alignment A_1A_2 in the direction of the course C_NC_N' of the enemy's center; it makes its alignment rotate through an angle ω, pivoting on the extremity A_1 farthest from the adversary. Since we leave it undetermined whether, with respect to the course of the fleet, the said extremity is farthest ahead or farthest astern, our reasoning is general and tends to establish the advisability of wheeling either on the head or on the rear.

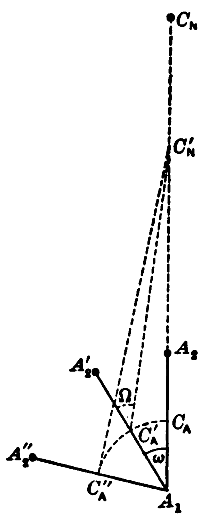

FIG. 28.

For simplicity's sake, let us suppose that A_1 remains stationary during the wheel; the center C_A of A takes the position C_A', and the new inclination of the alignment, counting from the line joining the centers, is $A_2'C_A'C_N'$, which we will indicate by Ω. As Ω is an exterior angle of the triangle $C_A'C_N'A_1$, we have

$$\Omega=\omega+C_A'C_N'A_1\text{; and hence }\Omega>\omega.$$

The advisability of wheeling upon A_1 would hence seem to result from the fact that, while the alignment rotates through ω, it really approaches the fundamental position through an angle greater than ω; while if the wheel were made about the extremity A_2, the contrary would happen; and, finally, if the rotation were made about C_A, Ω would be equal to ω.

In practice, in wheeling the alignment the pivot A_1 would not remain stationary, and, by reason of its movement, the angle Ω might be increased or diminished according to the circumstances

of the case.* So, also, the wheel on the intermediate ship, as has been said in Part I of this section, would not be made exactly about C_A; but all this does not weaken the general reasoning which would lead us to believe it advantageous to take as a pivot the extremity of the formation farthest from the enemy.

It is now necessary to determine the value of the difference $\Omega - \omega$; this is clearly at the maximum when $\Omega = 90°$; and, A_1A_2'' being the position of the alignment of the party A corresponding to such an hypothesis, from the triangle $C_A''C_N'A_1$ we get

$$\tan \omega = \frac{r}{\frac{1}{2}S},$$

S being the length of A's alignment, and r the distance $C_A''C_N'$, or the distance between the centers after the wheel. Supposing $r = 15{,}000$ meters, and $S = 5000$ meters, we have $\omega = 80°$ (about). Since the maximum value of the difference $\Omega - \omega$ is thus $10°$, it appears to be negligible, considering the rapidity with which the alignment may be rotated by pivoting about one-third of the length of the line from its head. Also, under the hypothesis $r = 10{,}000$ meters, we have $\omega = 75°$ (about), or $\Omega - \omega = 15°$. *The importance to be attributed to the wheel when pivoting on one of the extremities is hence restricted to that which results from the study made in Chapter I,* in which it was established that, within certain limits, it may be preferred to the evolution in succession when the line is very long.

As has been said, on account of the rapidity, pivoting on the ship about one-third from the head of the line is preferable to pivoting on one of the extremities. Nevertheless, being on a line of polar bearing, the evolution just mentioned may be advisable, as it avoids the initial passage to the column of vessels. Having regard to the amplitudes of the changes of course that the method requires it is seen that *it is best to pivot on the rear ship if the course is inclined in the direction of the new alignment, and on the leading ship if the course is inclined in the opposite direction.*

54. *Angular Alignments.*—The angular orders, so much esteemed when the ram was considered the principal weapon, seem

* If A_1 were the rear ship, the angle Ω would also be increased, because the displacement of the pivot would be in the direction A_1 A_2'; while, if A_1 were the leading ship, the displacement of the pivot would be in the direction A_2' A_1; on the other hand, since we know that the evolution on the leader is more rapid than in the other case, we must conclude that we are confronted with contradictory elements. (Author's note.)

today to acquire new importance, but on a different basis, for the reasons adduced in Chapter III of Part I (sections 18 and 20). As we there pointed out, the angular alignments are advisable in offensive contact for the purpose of having each of the elementary portions of a composite alignment in fundamental tactical position.

This advisability commences in contact out of range at the moment when the limit of offensive contact is about to be crossed, with the application of the following rule, the necessity for which seems obvious.

In contact out of range the fleet must be on a single line of polar bearing; if this is such that, when it is about to arrive at firing distance, one of the elementary alignments is in fundamental position, then, with such division taken as a pivot, the other elementary alignment may be changed so as to establish offensive contact in the most advantageous manner.

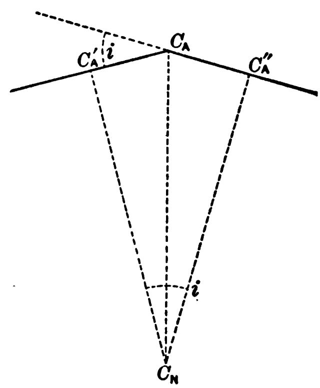

FIG. 29.

On the basis of this rule, under the hypothesis that the enemy has his forces compact, the limits within which the inclination i (Fig. 29) of the elementary alignment may vary, can be determined. Let C_A be the center of the alignment of the party A, and let C_A' and C_A'' be the centers of the elementary alignments.

Evidently the maximum value of i results under the hypothesis that the alignments must be in fundamental position with respect to one and the same elementary alignment of the enemy's formation which has its center at C_N. In such case we have

$$C_A'C_NC_A''=i;$$

and hence

$$C_A'C_A=C_A''C_A=C_AC_N \sin\frac{i}{2}.$$

Indicating by n the number of ships in the A party, by d the distance between adjacent ships, and by r the distance C_AC_N, we obtain

$$C_A'C_A=C_A''C_A=\frac{n-1)}{4}d;$$

therefore we have

$$\sin\frac{i}{2}=\frac{n-1}{4}\frac{d}{r}.$$

Making $n=12$, $d=500$ meters, $r=10{,}000$ meters, we get $i=16°$ (about). We may then hold $i=20°$ as the maximum value of i; hence the evolution may generally be executed by oblique courses with the speed ratio $\frac{8}{10}$. Evidently the pivot, instead of being a single ship, is composed of all the ships of the elementary alignment that it is desired to leave unchanged. The fact that the pivot is an assemblage of ships, renders inadvisable the application of the rule of De Gueydon for the double change of course.

It is easy to understand that, in order to obtain the object of the evolution, it is desirable that the ships forming part of the pivot should keep a course parallel to, and in the same direction with that of the enemy. If he makes a wide change of course, it is best to interrupt the evolution, assume the course that is deemed best, and then make another attempt.

When the angular alignment is brought about by the necessity of confronting an enemy broken up into independent groups that are not echeloned in distance—as represented in Fig. 11—the angle between the elementary alignments may be greater than that just found; in such case it is generally best to assume the angular alignment by interrupting an evolution in succession.

55. *Evolutions with a Double Alignment.*—One may be induced to perform evolutions with a double alignment (section 19), in contact out of range, by one of the following considerations:

1st. In contact out of range, as well as in offensive contact, it may be desired to keep the forces massed in that way.

2d. It is evident that one can perform evolutions more easily with a simple than with a double alignment of the same length; but it might be held that, given a certain number of ships, by placing them in double rather than in simple alignment, greater evolutionary facility might be acquired by virtue of the shortening of the line. Whenever evolutionary advantages with the double alignment present themselves, it might be employed in contact out of range, passing at the proper moment to the simple alignment in order to come into offensive contact.

A fleet in double alignment may be considered as formed by groups of four ships each in parallelogram (system of Labres *),

* See the résumé of Commandante Bonamico in *Rivista Marittima,* August-September, 1902.

or of three ships in a triangle (system of Fournier *) ; finally by groups of two ships, one in each line (twin system).

Let us consider evolutions performed by the ships in succession. The maximum simplicity and evolutionary rapidity would seem to be obtainable by causing each group of four ships to maneuver by simultaneous changes of course; in fact, small changes of the course of the naval force may be obtained by having each group make the change of course when it arrives in the wake of the preceding group. However, it is easy to see what inconveniences are encountered in so doing. Let us suppose a desire to change the alignment when the ships are on two lines of polar bearing and the lines joining the corresponding ships are normal to these lines of bearing, the distance between the lines being equal to the distances between ships, so that each group of four ships forms a square. By making all the ships of the fleet on the actual alignment change course simultaneously, we have the double column. In Fig. 30 there is represented a fleet composed of two groups that are already in that formation, and there is also shown the formation that results from a change of course in succession, following the rule above indicated. As is seen in the figure, the result is that *the ships are no longer in two lines, but in four;* and it is clear that they still remain in four lines when all the fleet executes the simultaneous change of course in order to return to the original course, or to take up a new course that is deemed advantageous.

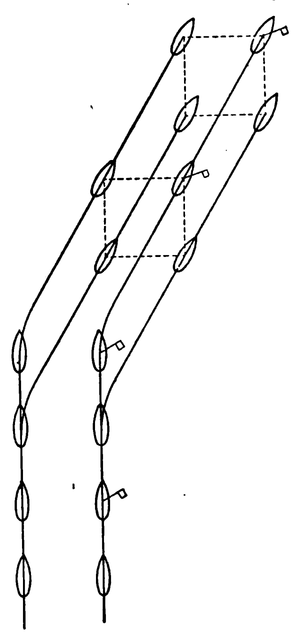

FIG. 30.

This sufficiently indicates that the method is not advisable, for the following reason:

* See *Rivista Marittima,* Vol. IV of 1907. In Fournier's system, the number of ships in one line of the alignment is half of that in the other line. With this system simultaneous changes of course are abandoned. (Author's note.)

In offensive contact, to the end that all the ships may fire, it is a necessary condition that they be not upon more than two lines. When the fleet is in two lines in contact out of range, on opening fire, it may be easy for the ships in the outer line with respect to the enemy, appropriately to modify their positions with respect to the ships in the inner line, so as to be able to fire through their intervals. This already constitutes a difficulty that, in practice, is not inconsiderable; but plainly we shall expose ourselves to the gravest risks if the matter is still further complicated by the fact that the ships are in more than two lines at such a critical moment. Analogously, if the groups of three ships each were maneuvered by simultaneous change of course, we should find ourselves forming three lines; which, for the same reasons, we believe are to be avoided.

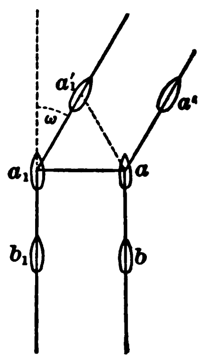

FIG. 31.

In evolutions performed in succession, the method of simultaneous changes of course may be adopted with the twin system only, for small changes of alignment. Indeed, let a, b, a_1, b_1 (Fig. 31), be four ships of the double column; when the ship b arrives in the water in which a has executed the change of course, the ship a_1 is in the position a_1' such that $a_1a_1' = a_1a = d$. To the end that, in the new alignment, the distance between the ships of the two lines may not fall below d, it is necessary to have $aa_1' \geqq d$, or $\omega \leqq 30°$.

This being said, we deem it indispensable that the evolutions of a double alignment should be executed on the basis of the following fundamental conditions:

1st, that the fleet be always in two lines. 2d, that, in general, the corresponding ships of the two lines should have each other bearing normally to the alignment; in fact, from this position the ships of the outer line with respect to the enemy, can, at the opportune moment and with the least possible difficulty, take the necessary positions for firing; and in this way we shall avoid a long alignment.

Furthermore, we shall hold that, generally, the number of ships composing the two lines should be equal, given the essential object which we have in view which is that of shortening the line.

The fleet may be drawn up on two lines of polar bearing α; α being any angle whatever, but the same for both lines. Let us

suppose the simultaneous change of course for passing to the double column to be already executed, as in the first position of Fig. 30, and let us see how, and in what time, the change of direction of the said column can be completed, in order afterwards to take up the advantageous course by a simultaneous change of direction.

From what has been demonstrated in section 41, it results that if two ships A and B, that have respectively the speed V_A and V_B, keep each other constantly bearing abeam, the tracks described by them are concentric circumferences. Letting ρ_A and ρ_B represent the radii of the circumferences AA' and BB' (Fig. 32), described respectively by A and B when $V_A > V_B$, and indicating by d the distance between the two ships (which remains constant dur-

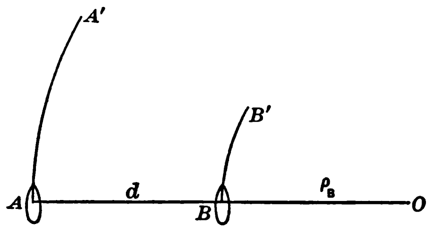

FIG. 32.

ing the movement), from formula (11) of Chapter I, substituting d for r therein, and making $\alpha=\theta=90°$, we have

$$\rho_B = \frac{d}{\frac{V_A}{V_B} - 1},$$

while

$$\rho_A = \rho_B + d = \frac{V_A}{V_B}\rho_B.$$

To the end that the condition $\rho_B = d$ may be realized, it is necessary to have $V_A = 2V_B$.

Now let it be noted that, between ships in formation, the tactical radius about equal to the distance d is that which is ordinarily employed when d is between 400 and 500 meters. It results, then, that, when in double column, the leading ship B of the inner line, with respect to the change of direction, puts his helm over, he must reduce his speed to one-half that of the outer line, of which the leading ship A, at evolutionary speed, must steer, keeping B, by sight vane, constantly abeam. The ships of the outer line must

keep up the speed in order to keep themselves abeam of their corresponding ships.

If n is the total number of ships in the fleet, each line is then composed of $\frac{n}{2}$ ships; and hence the time t occupied by the evolution is expressed by

$$t = \frac{\left(\frac{n}{2} - 1\right)d}{V_B} = \frac{(n-2)d}{V_A}.$$

If, instead, the fleet were in single line, the time occupied would be $\frac{(n-1)d}{V_A}$; which shows that the *abovementioned method requires a time only slightly different from that which would be occupied if all the ships were in a single line, and exactly corresponds to the time occupied by a single line having one ship less.*

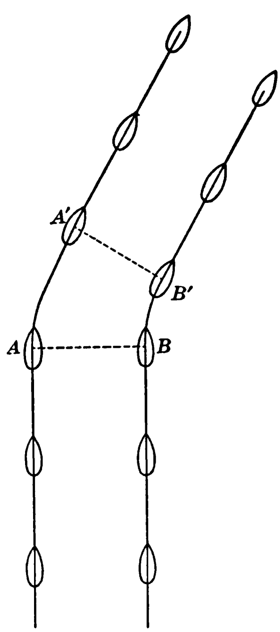

FIG. 33.

The method just indicated is general, and it is necessary to have recourse to it when the angle ω, through which it is desired to change the alignment, is of considerable amplitude; but, when ω is within certain limits, one can maneuver with greater quickness with the ratio $\frac{8}{10}$ between the speeds of the two lines, in the following manner:

The ship B, leading the inner line (Fig. 33), changes course through the angle ω in the desired direction, and assumes the proper speed for the abovementioned ratio; the leading ship A of the other line executes, with respect to B taken as a pivot, an evolution by oblique course, in order to bring itself again on the polar bearing 90°; that is to say, it completes—as is said in section 33, III—a wheel in line abreast; when A has made the wheel, that is, when it has arrived at the position A', it steers a course parallel to that of B and assumes the speed of B. The ships of each line follow their respective leaders in succession, and those of the outer line opportunely regulate their speed in order to keep themselves abeam of their corresponding ships. It is clear,

as Fig. 33 shows, that the change of direction to the new alignment will be completed when the last ship of the outer line arrives at A'; and, at the same time, the last ship of the inner line will be at B.

The duration of the evolution is hence

$$t=\frac{\left(\frac{n}{2}-1\right)d}{0.8V_A}+t_c=\frac{(n-2)d}{1.6V_A}+t_c;$$

t_c being the time necessary for the wheel of AB.

To the end that the duration of the evolution with the method may be less than that corresponding to the method by concentric circumferences before alluded to, we must have

$$\frac{(n-2)}{1.6}\frac{d}{V_A}+t_c<\frac{(n-2)d}{V_A}.$$

Making $\frac{d}{V_A}=t_0$, this inequality is transformed into another:

$$\frac{t_c}{t_0}<0.38(n-2).$$

The formula that gives the duration of the wheel of two ships in line abreast at the distance d, by virtue of what has been demonstrated in Chapter I, is

$$t_c=\frac{2d\sin\frac{\omega}{2}}{V_A\sqrt{1+\left(\frac{V_B}{V_A}\right)^2-2\frac{V_B}{V_A}\cos(\omega-\phi)}},$$

in which ϕ is the angle of change of direction for said wheel, which angle is equal to $\omega+\delta$; δ being the angle obtained from formula (3) of Chapter I, by placing in it $\beta_1=90°+\omega$; in this way we get

$$\phi=\frac{\omega}{2}+\text{arc}\sin\left(\frac{V_B}{V_A}\sin\frac{\omega}{2}\right),$$

wherein, in the case we are discussing, we must put $\frac{V_B}{V_A}=0.8$.

There are thus obtained the values of $\frac{t_c}{t_0}$ which are set down in the following table:

ω	$\frac{t_c}{t_0}$	n
15°	1.31	6
30°	2.59	10
45°	3.48	12
60°	4.54	14
75°	5.08	16
90°	5.87	18

With the values of $\frac{t_c}{t_e}$, taking into account the inequality above deduced, the values of n in the third column are calculated; which values indicate, for each value of ω, the minimum number of ships of which the fleet must be composed in order that the evolution performed in succession, following the wheel of the leading ships, may be advantageous with respect to the evolution by concentric circumferences.

It results from the preceding that, *in evolutions performed in succession, a fleet must be very numerous in order that it may be maneuvered on a double alignment with greater rapidity than on a single alignment.* Indeed, if the number of units is not very considerable, the angle ω must likewise be limited in order that the method by wheeling the leaders may be sensibly advantageous over that by concentric circumferences; which, in its turn, occupies a length of time not sensibly different from that required by a simple alignment. So, in order to fix the ideas, let us note that with twelve ships on a simple alignment, the evolution would require a time $11 \frac{d}{V_A}$; while with the method of concentric circumferences the time would be $10 \frac{d}{V_A}$, and, with the wheel, for $\omega = 45°$, there would be a duration of $9.7 \frac{d}{V_A}$. However, the advantage of this last method is rendered sensible with smaller values of ω.

The evolution by oblique courses, in order to satisfy exactly the two conditions established as fundamental, must evidently be executed according to the following rules:

1st. Simultaneous change of course in the direction perpendicular to the alignment. The fleet is thus arranged in two lines abreast, and the corresponding ships of the two lines are in column of vessels.

2d. The ships of the first line make a wheel in line abreast of the amplitude through which it is desired to change the alignment; the ships of the second line follow in succession, opportunely regulating the speed in order to maintain the distance from the corresponding ships of the first line.

3d. The advantageous change of course is assumed with a simultaneous change of direction.

It is needless to demonstrate that this evolution is little adapted to tactical necessities.

In double column the alignment might also be changed by wheeling each of the two columns so formed; but it is to be noted that there is applicable to such a case the observation already made in this section in connection with evolutions performed in succession by means of simultaneous changes of course of the successive couples of ships; that is to say, the said wheel must be less than 30° in order that the distance between the ships of the two lines at the end of the evolution may not fall below the normal distance.

We are now able to formulate the following conclusions concerning the tactical management of a double alignment.

Having a number of ships greater than twelve, the double alignment is convenient; evolutions with it must generally be performed in succession. Evolutions by oblique courses are long and complicated; hence it is difficult to take up in that way an angular alignment, and when the latter is deemed necessary, it must be assumed by interrupting an evolution performed in succession.

With about twelve ships or less, the double alignment would allow some advantage over the simple alignment in the case of evolutions performed in succession; but it must be borne in mind: 1st, that this advantage is sensible only within very narrow limits; 2d, that with the fleet on a double alignment, evolutions by oblique courses are performed with great difficulty; 3d, that, desiring to pass to a simple alignment at the moment of coming into offensive contact, an evolution would be necessary, which, on the other hand, would not be necessary if the forces were kept on the simple alignment from the start. In short, with a not very numerous force, keeping it, in contact out of range, on a double, instead of on a simple alignment, there would be a diminution rather than an increase of the maneuvering qualities of the fleet.

Finally, as pointed out in section 19, the double alignment may be advisable for the purpose of using antiquated ships in the second line; it is clear, however, that the number of such ships must be limited, so as not in the least to encumber the maneuvering of the line composed of modern ships. The double alignment formed in this way can be maneuvered as a simple alignment when the antiquated ships are not deficient in speed, and when there is only one of them for every three or four ships of the real line of battle. The said ships of the second line, without any suggestion of exactly determined positions, will regulate themselves

in the most opportune manner in order not to embarrass the maneuvering of the principal line.

56. *General Considerations Concerning the Evolutions of Compact Forces.*—Admiral Makaroff notes how it may be well to interrupt an evolution that is in progress. "While the fleet is changing its formation," he writes, "it remains in a transitory state of maneuvering, and the admiral can undertake nothing during that time without risk of causing confusion. A case, however, may arise wherein a change of formation ought to be arrested in order that all the ships may execute a simultaneous change of course. Short signals should be employed, and we proposed that the signal 'Come along!' (Via!) be hoisted. All the ships must then, as quickly as possible, assume a course parallel to that of the admiral and thus afford him the possibility of maneuvering."

These considerations are to be borne in mind. It may be important to interrupt an evolution when a change of course is urgent, or because the new alignment signalled is no longer deemed opportune. As the ship of the commander-in-chief may not be at an extremity of the line, let us establish that, in interrupting an evolution, the ships must assume a course parallel to that of the guide ship (regolatrice).

The possibility that an evolution by oblique courses may have to be interrupted, and that for this reason a disorderly formation may result, shows us the special importance that must be attached to evolutions performed in succession; indeed, with this method, after having changed course on the initial alignment and while the ships are changing direction successively in order to arrange themselves on the new alignment, if it is discovered that the said new alignment is not satisfactory, the leading ship can change course, causing itself to be followed in succession in order to form another alignment. Hence, evolutions performed in succession do not require prevision of the tactical situation at the end of the evolution in the same degree in which such prevision is required by the method of oblique courses.

Between two fleets opposing each other which at any given instant may have alignments equally inclined to the line joining their centers, differences may be created by the following causes:

1st. *Difference of speed;* in fact, with equality and simultaneity of maneuvering, the swifter party can deploy a greater number of ships.

2d. *Difference in the length of the alignments;* when they are of the same kind (simple or double).

3d. Delay in the execution of the counter movement.

This being the case, of the two adversaries, we will say that the better maneuverer is the one that has the greater speed when the two alignments have equal lengths, or that has the shorter alignment when the speeds are equal.

It is easy to admit that, for the party that is the worse maneuverer—which we will indicate by *N*—it is well, on sighting the enemy, to assume an alignment normal to the line joining the centers (the fundamental position), while for the party *A*, the better maneuverer, it may be well to assume a different alignment.

In short, let us suppose that, in this last case, the worse maneuverer does not assume an alignment in the fundamental position, but contents himself with keeping an alignment equivalent to that of the enemy. By virtue of his better maneuvering qualities, the party *A*, on coming into offensive contact, can assume an alignment in the fundamental position with greater celerity than the enemy, or can acquire an advantageous initial position.

The interest that the better maneuvering party may have in assuming an alignment different from the normal to the line joining the centers, lies in the probability of leading the enemy into error.

Two cases, then, may present themselves to the better maneuvering party *A:* 1st, the enemy's alignment is not in the fundamental position; 2d, the enemy's alignment is in said position.

In the first case, it is well for the party *A* to assume, on sighting, an alignment equivalent to that of the enemy, changing it at an opportune moment in order to be in an advantageous position on coming into offensive contact.

In the second case, it is clear that the greater the amount of maneuvering, the more *A* can draw advantage therefrom. In other words, it is well for *A* to move toward one of the extremities of the enemy's line, obliging him to maneuver in his turn in order to keep himself in the fundamental position; in this way *A* can make an advantageous entry into the zone of fire. The counter movements of *N* will naturally be inspired by the idea of not allowing the enemy to arrive at firing distance in a superior position; and for this purpose he must have recourse to changes of bearing, keeping the enemy abaft the beam. Under such condi-

tions each of the adversaries will seek, in maneuvering, to lose the least ground possible in the direction of the advantageous course, unless they are so near to the distance for opening fire that they must seek rapidity of evolution above everything else.

On the basis of what has been said, we must hold that unless one of the parties is, to a certain extent, passive, *the phase of contact out of range will be a phase of active maneuvering,* and will produce differences in the initial conditions of position on the establishment of offensive contact. In the following chapter we shall see how this initial situation may affect the tactical maneuvering.

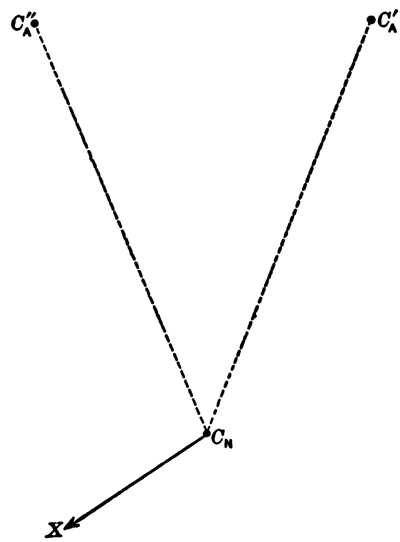

FIG. 34.

57. *Independent Groups in Contact out of Range.*—The breaking up into groups, already alluded to in section 20, appears to be opportune as regards maneuvering, for the following reasons:

1st. The duration of an evolution of a compact fleet is proportional to the length of the alignment, with equality of form of the latter.

2d. By placing the swiftest divisions at the extremities of a line, as has been said in this chapter, the utilization of their speed may be obtained, but only in some special case. In maneuvering by independent groups we may, on the other hand, tend to draw the

maximum return from the maneuvering qualities of each group, in a continuous manner, when each of them is sufficiently homogeneous as regards speed.

Let us now consider the maneuvering of a fleet formed by two independent groups, opposed to a compact fleet, in contact out of range; bearing in mind that we have already recognized the necessity, in offensive contact, of avoiding the echeloning of groups in distance.

The speed of a fleet being determined by that of its slowest unit, it is necessary to distinguish two cases:

I. Each of the independent groups has a speed superior, or at least equal, to that of the party that remains compact.

II. One of the independent groups has a speed inferior to that of the enemy's fleet.

Under the first hypothesis, if the forces that maneuver by groups sufficiently understand each other, so that, although independent, they may rely upon maneuvering in a co-ordinate way, from the maneuvering by groups the abovementioned advantages may really be hoped for, although the enemy maneuvers well. A group will maneuver so as to be at the same distance from the enemy's center as the regulating group, keeping the most opportune alignment according to the rules already established. Although, with regard to the momentary positions, an inferiority of conditions for the compact fleet does not exist—as we have pointed out already—still we must hold that it may result in practice, because the compact fleet is the poorer maneuverer.

In the second case, in order to discover the dangers of breaking up into groups, it is necessary to suppose that the enemy maneuvers in the way that is best for him. Let C_N, C_A' and C_A'' be respectively the positions of the centers of the party N that remains compact, and of the groups A' and A'' into which the party A is divided. The speed V_N of the party N is greater than the speed V_A' of the group A'. From what was demonstrated in Chapter I, it readily results that if N follows a course C_NX, such that the polar bearing XC_NC_A' is equal to or greater than $90° + \text{arc} \sin \dfrac{V_A'}{V_N}$, the distance C_NC_A' continually increases, whatever may be the course of A', because this is the case in which for the slower party, the problem of approach admits of no solution.

This said, it is clear that the course of *N* may be such as to avoid the approach of *A'*,* producing at the same time the removal of *N* toward *A''*.

Under such conditions, if offensive contact is brought about, it will be between the compact party and one of the groups of the other combatant; and in order properly to understand why, in such case, *A* has not the advantage in maneuvering power alluded to in the hypothesis previously discussed, it is well to reflect that, if the course of *A''* is favorable to the approach, the party *N*, given its presumable superiority with respect to such group, has to trouble itself about the alignment in a much smaller degree than would be required against an adversary of superior or equal strength.

These considerations suffice for concluding:

1st. The necessary condition for breaking into independent groups is that each group shall have a speed not inferior to that of the enemy's fleet.

2d. When the enemy is broken up into independent groups, and one of his groups has a speed inferior to that of our total force, the conduct of our force must be conformed to the rule of moving in the direction of the swifter group, thus avoiding the nearer approach of the slower group.

* The course of *N* must naturally be established, taking into account the length of the formation; that is to say, it must be the most opportune for the ship that could most easily be approached by *A'*. (Author's note.)

CHAPTER IV.

TACTICAL MANEUVERS.

58. *Maneuvers in Column of Vessels.*—As has been pointed out in section 48, the fundamental conditions which the tactical maneuvers ought to satisfy are the following: 1st, not to disturb the firing; 2d, allow the immediate and continuous adaptation of the proper maneuver to that of the enemy, each ship imitating the movements of the guide ship as a directive.

It is clear that the simplest tactical maneuver that has the requisites enumerated, and which permits of keeping the fleet perfectly ordered, is the one performed in succession in column of vessels.

For these reasons the importance that is generally attributed to the column of vessels is justified. It is well to note, however, that, conformably to the idea several times repeated, a line of conduct contrary to the spirit of modern tactics and binding one to a fixed formation could be followed; and so, when there is a question of the column of vessels, it is generally to be understood that we do not refer to the ships in that formation keeping the course constant for long intervals, but it is implicitly the idea that the course of the leading ship is generally changeable in a slow but continuous manner, conformably to the standards established for an isolated ship; *hence we refer to maneuvering in column of vessels rather than to the formation of that name.*

Such maneuvering appears the more worthy of consideration inasmuch as the adversaries in the recent Russo-Japanese War confined themselves to it; its importance is incontrovertible, owing to the fact that it requires the minimum amount of preparation on the part of the commander; so that it is indispensable to adopt it when one has at his disposal forces that have had but little drill; but outside of this case, it is well to put the prejudicial question, asking ourselves if the said form of maneuvering is always advisable, so that, admitting its simplicity, we may excuse ourselves from studying other forms.

Against an enemy in column of vessels, the criteria established in section 15 for the selection of ships upon which to concentrate the fire, must be supplemented by taking also into account, besides the firing distance, the disorder that is produced in the enemy's

formation by obliging one ship to fall out of the line rather than another. The advisability of each elementary alignment concentrating its offense on the leading ship of the corresponding division of the enemy rather than on the rear ship is evident, unless, in firing on the rear ship, it is possible to carry on the firing at shorter distances. It is apparent, then, that, *as between two adversaries in column of vessels with courses parallel and in the same direction, the advantageous position must be held to be the one farther advanced in the direction of the course.*

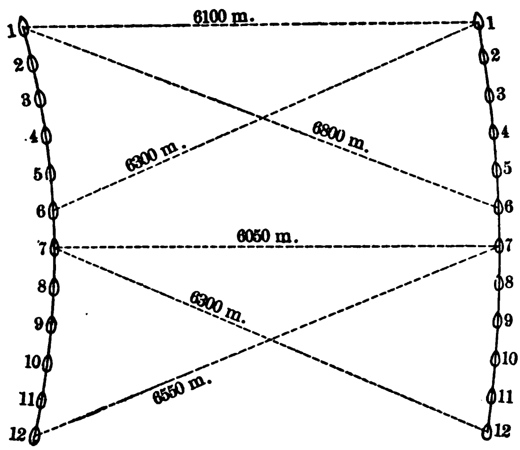

FIG. 35.

Let us consider the hypothesis that the fleets opposing each other, both in column of vessels, have, in offensive contact, alignments in the fundamental tactical position. From what has just been said in regard to concentration, if neither of the adversaries desires to change the distance, they will maneuver in such fashion that their respective center ships may have courses perpendicular to the line joining the centers, and that each may steer in the direction toward which the enemy is moving. Having alignments of the same length, in order to apply this criterion the two adversaries move initially with courses parallel and in the same direction, and the corresponding ships of the two lines will have each other mutually bearing abeam.

If a difference of speed exists between the two adversaries, the swifter party will gain in the direction of the course, thus tending to acquire an advantageous position.

It is evident that each of the two adversaries will seek to maneuver in order to keep itself in the fundamental position. Fig. 35 shows such an object attained; the centers of the alignments have each other constantly bearing abeam. The alignments are, as we already know, concentric circumferences; the ratio of their radii is equal to the ratio of their speed, and the radius of the inner circumference is expressed by $\frac{r}{\frac{V_A}{V_B}-1}$, r being the distance between the centers, V_A and V_B the respective speeds ($V_A > V_B$).

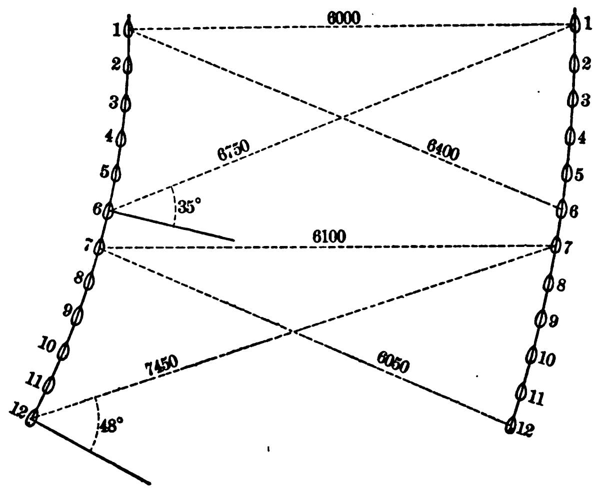

FIG. 36.

The figure corresponds to the hypothesis $r = 6000$ meters, $\frac{V_A}{V_B} = 1.5$ for the usual interval of 500 meters between ships. As shown by this, the situations of the two adversaries may be considered as equivalent; so much the more so if the speed ratio is inferior to the one supposed.

A situation nearly like the one indicated, and which is often discussed by the students of tactics, is realized when the two leading vessels, steering by sight vane, mutually keep each other bearing abeam; the radii of the circumferences are still those abovementioned, with the difference, however, that in this case r is the distance between the leading ships.

There is thus produced the tactical situation of Fig. 36, which must be held to be advantageous for the swifter fleet for the following reasons: 1st, the center of such fleet is removed forward of the beam of the enemy's center; 2d, the alignment of the said fleet is concave, while that of the other is convex, which causes it to befall that some ship does not present a sector of maximum offense. Such advantages increase with the diminution of the distance and with the increase of the ratio $\frac{V_A}{V_B}$.

With the supposed data, as the firing distances marked in the figure show, the swifter fleet has a sensible advantage; but the value $\frac{V_A}{V_B} = 1.5$ is certainly greater than those that are realized in practice; we may, therefore, affirm that, *in general, by making the abovementioned maneuver, the two adversaries are in equivalent tactical situations which will remain stationary.* Since the situation of the fleets is comparable to that of two single ships opposing each other and which constantly present the beam to each other, by analogy with what we said in Chapter II, we cannot hold it to be rational.

We are thus in condition to affirm that, against an enemy maneuvering in column of vessels, we may not presume, by imitating him, to acquire an advantageous tactical position, even if we possess a notable advantage in speed, *unless we have also a notably shorter line.* Indeed, Figs. 35 and 36 show how two adversaries that present to fire sides of opposite names may be in equivalent positions; it happens analogously between two adversaries who are in fundamental position in column of vessels, with courses parallel but in opposite directions, each of whom changes direction in succession with intent to assume an advantageous position. In this case the alignment of the slower party also turns its concave side to the enemy.

It is readily seen that, for changing the distance, maneuvering in column of vessels is hardly advisable. For such purpose, let us consider the ships of an elementary alignment that concentrate their fire on one of the enemy's ships. In order that the concentration may be possible, it is necessary for the ship nearest the said enemy's ship to have it bearing in a direction near the beam; sufficiently near, at least, to allow the most distant ship to fire in a limit direction of a sector of maximum offense.

Let us refer to what we noted in section 37 concerning the radii of curvature.

If the two adversaries expose to fire sides of opposite names, the radius of curvature of the track described by the party that maneuvers in column of vessels is necessarily very great, and hence the track may practically be considered rectilinear for a segment of a length equal to that of an elementary alignment.

This being the case, solving the triangle formed by the alignment and the two lines joining its extremities with the said enemy's ship, it is perceived that if, for example, the sectors of maximum offense extend to 45° from the beam, the nearest ship must hold the said enemy's ship by sight vane in a direction at least 60° from the longitudinal axis. In such case, *the ships maneuvering in succession in column of vessels are in the condition of a single ship whose sectors of maximum offense do not extend farther than 30° from the beam;* or, maneuvering in succession, one may not generally rely upon controlling the development of the action.

When the two adversaries present to fire sides of the same name, the radii of curvature are greatly reduced; but, even if the concavity of the alignment toward the enemy is sufficient to annul the abovementioned inconvenience, *it does not do away with the fact that the alignment of the party that maneuvers in succession is inclined to the line joining the centers;* while, if the enemy's alignment is in fundamental position, it is obvious that he can oppose changing the distance by opportunely inclining his ships on the alignment.*

* Whoever wishes to study the question in a theoretically more exact way may profit by the knowledge of the following theorem: If two ships steer keeping themselves on constant polar bearings, not only is the indicator of relative movement an equiangular spiral, as we have already had occasion to mention (see note to section 36), but the tracks actually followed by the two ships are also equiangular spirals which are inclined at the same angle with the radius vectors leading from the pole which is common to both. The angle of inclination of the spirals, adopting the usual symbols, is given by the formula

$$\tan i = \frac{V_B \sin \theta - V_A \sin \alpha}{V_B \cos \theta - V_A \cos \alpha}.$$

It results from this that, if one of the two ships is followed by others in succession, the alignment is on an arc of an equiangular spiral.

Lieutenant L. Tonta has occupied himself with this theorem in a valuable article in the *Rivista Marittima* of March, 1901. The question has

Hence, maneuvering in succession may lead to a disadvantageous situation; it lessens the capacity for tactical initiative, because in adopting it *we are obliged to change the alignment, when all that is necessary is a change of course.*

Evidently, the inconveniences of the column of vessels are increased with a composite alignment; that is to say, the greater the number of ships that follow the leading ship.

The advisability of having the ships inclined to the alignment has been alluded to. In general, the idea of keeping the alignment constant for considerably long intervals of time, changing the inclination of the ships to it according to need by means of simultaneous changes of course, does not seem acceptable, because this may permit an adversary who maneuvers in column of vessels to take advantageous positions; this means, opposing a rigid alignment to another eminently flexible; and, for simultaneous changes of course, signals are rendered necessary.

It would, therefore, seem advisable to establish maneuvering in column of vessels as normal, yet not excluding fighting on lines of bearing because of the simultaneous changes of course that may eventually be required; but the defects which we have recognized as attributable to maneuvering in column of vessels lead us to seek a better system.

Maneuvering by simultaneous changes of course presents the aforesaid inconveniences when the changes are intermittent; but we have already alluded (section 17) to a form of alignment (at equidistant positions) which appears susceptible of being maintained in fundamental position; let us seek to develop this idea by procuring the elimination of the inconveniences of maneuvering in column of vessels without falling into that of rigidity of alignment.

We propose to see whether it is allowable to hold as normal the maneuver known as keeping the alignment at equidistant positions, having recourse to the column of vessels as a transitory formation for the evolutions.

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been discussed in France in divers articles published in the years 1875, 1876 and 1880 in the *Revue Maritime;* the results of these studies are set forth in Chapter II of *Manuel pratique de Cinematique navale* by Comdr. L. Vidal (1905). In practice, however, for the length of the alignment, the equiangular spiral may be considered as an arc of a circle the radius of which is given by formula (11) of Chapter I. (Author's note.)

Such importance as a transitory formation may be admitted without further argument, observing that, if it is necessary notably to change the alignment, the evolution must be such as not to render perilous the effects of an erroneous prevision of the tactical situation at its end; or, at such a moment, it is best to be in column of vessels. *The evolutions that we must examine for the change of alignment in offensive contact are thus reduced to that performed in succession and those based upon wheeling the column of vessels* (section 53).

59. *Maneuvering at Equidistant Position.*—By virtue of what we said in section 17, an elementary alignment opposed to another may practically be considered an arc of a circle having its center at the center of the enemy's alignment, when, an extreme ship

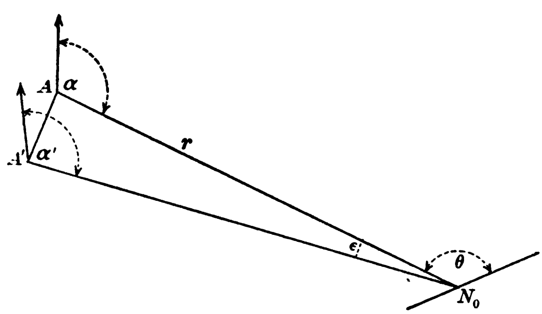

FIG. 37.

being taken as the regulator, every ship is in a position such that the angle between the line joining it with the adjacent ship in the direction of the regulator and the line joining it with the aforesaid enemy's center, is 90°.

Supposing the ships to be on such an alignment, we propose to study the maneuvering that permits of maintaining it.

Let us consider two adjacent ships A and A' (Fig. 37) of an alignment at positions equidistant from N_0, having as a radius the distance r; the angle $AA'N_0$ being 90°. Let us indicate by d the distance AA' and by ϵ the angle AN_0A'; we then have

$$\sin \epsilon = \frac{d}{r}.$$

Let α and α' be the polar bearings on which, at the instant under consideration, the respective ships A and A' hold N_0; these bearings being counted from the bow. If θ is the polar bearing on

which A is held by N_0 (counted from the stern), the analogous bearing for A' could be $\theta+\epsilon$ or $\theta-\epsilon$. We will indicate by V, V' and V_N the respective speeds of A, A' and N_0.

Let us note first of all that if there exists the relations

$$V \sin \alpha = V_N \sin \theta,$$

the indicator of movement of A with respect to N_0 is given by the joining line AN_0; and hence, in order to preserve the alignment in the fundamental position, the ship A' (and, more in general, the ships of the alignment opposed to N_0) must keep the course and speed of A.

While not excluding the possibility that the conditions just mentioned may be realized in practice, it is readily seen that this method *with uniform speed and course* cannot be held to be general, because it is not logical to establish the aforesaid relation as a necessary condition; let us, however, seek to determine the criteria for maneuvering at equidistant positions in a way that may permit the maximum freedom of execution. Let us see if it is acceptable to carry out the maneuvering by the two following methods:

1st. *At uniform speed;* that is to say, with the ships A and A' maneuvering at the same speed V which, in general, naturally requires different sight-vane angles α and α'.

2d. *With a uniform sight-vane angle,* which ordinarily requires that the ships A and A' have different speeds V and V'.

In both cases the ships of the A party must move in such a way that, in the time dt, they may have the same change dr in the distance from N_0. If we wished to calculate the unknown values α' and V' it would then suffice to apply the fundamental tactical relation. Thus, for the method at a uniform speed, we have

$$V_N \cos \theta - V \cos \alpha = V_N \cos(\theta \pm \epsilon) - V \cos \alpha'. \qquad (1)$$

Naturally, when the value of $\cos \alpha'$ supplied by this formula is not, in absolute value, less than unity, it means that the method is not applicable.

For the other method, in the foregoing relation it would be necessary to put $V' \cos \alpha$ in place of $V \cos \alpha'$; in other words, we may say that the value of V' must satisfy the condition

$$V' \cos \alpha = V \cos \alpha', \qquad (2)$$

wherein it is necessary to introduce the value of $\cos \alpha'$ obtained from (1).

Applying these methods, evidently the distance AA' does not remain invariable.

In order to fix these ideas, let us consider the simplest hypothesis, which is that of a stationary enemy. Putting, in formula (1), $V_N=0$, we have $\alpha'=\alpha$; which, introduced into formula (2), gives $V'=V$; hence, in the particular case to which we now refer, the two methods just mentioned are combined, the ships being able to maneuver with uniform speed and sight-vane angle. Against a low fort, or a ship at anchor, such maneuvering may be opportune, because it permits the ships of a homogeneous division to keep the enemy bearing in a direction of maximum utilization.

We may, then, in a very simple way, extend the rules established for maneuvering an isolated ship to the maneuvering of a division; because such rules, in the case of a stationary enemy, evidently lead to maneuvering at a limited distance, keeping the enemy bearing in directions of maximum utilization alternately forward of and abaft the beam.

In such case the joining lines AN_0 and $A'N_0$ both revolve through the same angle, because formula (10) of Chapter I (section 37), becomes

$$\frac{d\sigma}{dt}=\frac{V \sin \alpha}{r}.$$

The angle ϵ under which the ships A and A' are seen from N_0 thus remains invariable; therefore, when the radius of the equidistant alignment passes from a value r_1 to a value r_2, the distance AA' changes from a value d_1 to d_2; and there is realized

$$\frac{d_1}{r_1}=\frac{d_2}{r_2};$$

both the members of the equation being equal to sin ϵ. Consequently, if r_1 and r_2 are respectively the superior and inferior limits between which it is predetermined to maintain the distance from the enemy N_0, when the maneuvering is begun at the superior limit of the fighting distance it is necessary that the distance d_1 between ships be established as somewhat greater than the allowable minimum, remembering that during the maneuvering it will be reduced to d_2. When, as generally happens, the ratio $\frac{r_2}{r_1}$ is not inferior to $\frac{7}{10}$, it might seem opportune to establish for d_1 the value that is ordinarily assumed as the normal; and this in conformity with what is said in the preceding chapter concerning

the diminution of the distance allowable during the evolutions. It is clear, however, that in every tactical maneuver this tolerance may obtain within narrower limits; thus, in the special case that we are considering, it is necessary to remember that, at the instant at which the ships find themselves at the minimum distance, they must execute a simultaneous change of course in order to bring the enemy to bear abaft the beam; it is, therefore, well to establish that the normal distance between ships shall be realized for the mean distance $\frac{r_1+r_2}{2}$ from the enemy, rather than for the maximum distance r_1.

For example, supposing the limits between which it is desired to keep the firing distance to be 10,000 meters and 7000 meters, and the normal distance between ships to be 500 meters; to the end that the latter may correspond to the mean distance (8500 meters) from the enemy, it is necessary for the ships, when they begin the action at the distance of 10,000 meters, to have an interval between them of 600 meters; and, by reason of the maneuvering, at the limit of the approach it will be 400 meters; which will always be sufficient.

Such an amount of oscillation (100 meters more or less than the normal distance) is allowable even against an enemy's fleet in motion; and in fact it is well to observe: 1st. That, theoretically, every increase in length of the alignment constitutes a disadvantage of position; however, as we have already observed in Chapter III of Part I, if the difference in length between two opposing alignments is 500 or 1000 meters, it may be held to be negligible in practice, because only a small part of it affects the conditions of position. 2d. The normal distance between ships must of necessity be established as somewhat greater than the minimum which confers safety of maneuvering.

Without doubt, then, we may affirm that, having regard to maneuvering at equidistant positions in the general case of an adversary in motion, it is well to be governed by the following rules: 1st, watch the variations of the distance between ships, with the understanding that these variations are to be kept within sufficiently narrow limits; 2d, it is well that the distance between ships at the limit of offensive contact should be somewhat greater than the normal.

This being established, we make the following reflections:

The method at uniform speed is naturally that which at first sight appears to be preferable; but it may possibly lead to varying the distance between ships beyond the desired limits. On the other hand, the method with a uniform sight-vane angle might require a ratio $\frac{V'}{V}$ differing too much from unity.

Let us note that, for the maneuver in question, the ship A', in order to keep the speed V, should keep N_0 bearing at an angle α', while the polar bearing α would correspond to the speed V'; hence, to a bearing α_1 intermediate between α and α', there will correspond a speed V_1, intermediate between V and V'; or, the ratio $\frac{V_1}{V}$ will be nearer to unity than $\frac{V'}{V}$.

We recall further that, while the ship N_0—from which it is desired to keep the ships of the alignment at equidistant positions —is the one that occupies a central position in the enemy's alignment, the ship upon which ordinarily it is best to concentrate the offense, is an extreme ship of the said alignment. It results from this that the extreme ship of our own alignment, which serves as a regulator, must keep the enemy's ship for the concentration of fire at an opportune sight-vane angle which will be established according to criteria of which we will shortly speak; the polar bearing of N_0 will be the one which will derive as a consequence of this. If, thus far, we have referred to the polar bearing of N_0, it has only been for the sake of simplicity of reasoning.

The criteria sought for the execution if the maneuvering at equidistant positions may be established in the following manner.

Let us suppose our alignment to be in the fundamental position, and that the ships have all the same course, so that they are on a line of polar bearing. An extreme ship, taken as a regulator, keeps the enemy's ship for the concentration of fire on an opportune bearing, and, more in general, maneuvers, with respect to the said enemy's ship, in a way conformable to the criteria determined upon in the study of the naval duel; thus describing, generally, a curvilinear track with a great radius of curvature.

Each ship continually imitates the movements of the adjacent ship in the direction of the regulator in such fashion as to keep itself in the position from which may result the angle of 90° between the line joining it with the said adjacent ship and the one joining it with the center of the enemy's alignment. With such

object it may slightly modify its course with respect to the adjacent ship, but within a limit that does not produce too notable variations of distance. Such limit being reached, it is best for the said ship to vary the speed in order to preserve the desired position.

Briefly, it may be said that *a ship must imitate the movements of the adjacent ship; that is, keep on a course about parallel to it, slightly modifying its course and speed in order to satisfy the 90° rule.*

Thus *the way to carry out the maneuvering at equidistant positions is by the fusion of the methods before alluded to.* It is evidently well to ordain that the regulating ship be the inner one on the side of the changes of course necessary for steering by sight vane, and it is generally advisable for the said ship to maintain a speed slightly inferior to the normal speed,* to the end that the maneuvering may be facilitated for the other ships; or, in order to increase their reserve of speed. It is possible that the reserve of speed of the other ships may not be sufficient for maintaining the alignment in fundamental position; nevertheless, it is easy to see that the most rational criterion for maneuvering remains as abovementioned; indeed, in such case, although not fully attaining the object of keeping the alignment in fundamental position, we approximate to it as nearly as possible.

If the regulator ship develops the maximum speed, the application of the prescribed rule causes the ships to change course in a continuous way parallel to it; *and the formation becomes a line of polar bearing, in which, however, the bearing may be slowly variable,* the ships executing continuous but very slow changes of course with a great radius.

* As has been said in the preceding chapter (section 49), the normal speed is inferior to the evolutionary speed which is generally the maximum speed of the slowest unit. When the alignment is changed by wheeling the column of vessels, it is necessary for the pivot ship to reduce its speed to one-half of the evolutionary speed; but, in the case of maneuvering at equidistant positions, the reduction of the speed of the regulator ship must be kept within restricted limits, enabling the speed to be maintained. In like manner to that of limiting the reductions from the maximum to a speed inferior by four or five knots—established for the naval duel—it is well to ordain that the speed of the regulator ship in the maneuvering under consideration shall not fall more than three knots below the normal speed. (Author's note.)

Let us now consider a composite rectilinear alignment; that is to say, two contiguous elementary alignments placed one on the prolongation of the other, or an angular alignment. It is clear that, in each elementary alignment, it must be sought to maneuver at positions equidistant from the enemy's corresponding alignment. One of the elementary alignments acts as a regulator; and the extreme ship of the other alignment, adjacent to the outer ship—with respect to the change of course—of the regulator alignment, imitates the movements of the latter, modifying its speed in the manner most opportune for the object that it is desired to secure.

From the foregoing we may conclude:

1st. The tactical maneuvering to be held as normal is that at equidistant positions; there results from it a flexible alignment, capable of being adapted in a continuous manner to the changeableness of the tactical situation, without disturbance to the firing.

2d. The said maneuvering admits, as a particular case, having a *constant alignment,* in which an extreme ship steers with the sight vane on an enemy's ship, and the others imitate its movements, tending to keep the courses parallel.

3d. The type of maneuvering just indicated presents no dangers, the inner ship on the side of the changes of course being chosen as the regulator, and the said changes being with a great radius resulting from steering by sight vane.

60. *Inclination of the Ships to the Alignment.*—Let us now see what conditions must be satisfied by the inclination of the ships to the alignment, to the end that it may be possible to concentrate the fire, while presenting the ships in the most opportune manner as regards offensive as well as defensive conditions.

Let N_1 (Fig. 38) be the enemy's ship on which it is desired to concentrate the fire, and A_1A_2 an elementary alignment at positions equidistant from the center N_0 of the enemy's alignment which, in the figure, is supposed to be in the fundamental position; but which, naturally, could also be inclined with respect to the line joining the centers.

For the determination with which we are now occupying ourselves we may hold that the various ships of A_1A_2 have about the same course. The ship A_1, which is at the extremity of the alignment nearest to N_1, desires to bring that ship to bear in a limit direction of a sector of maximum offense; it might do this by hav-

ing its longitudinal axis * in the direction XX' or in the direction YY'; XX' and YY' being symmetrical with respect to N_1A_1.

It is clear, however, that, in the case of YY', the other ships of the alignment would have N_1 bearing in a sector of minimum offense; while if the longitudinal axis of A_1 is in the direction XX', the other ships can have N_1 bearing in a direction inside of a sector of maximum offense. Naturally the bows of the party A must be in the direction A_1X, or in the direction A_1X', according as A desires to bring the enemy to bear abaft or forward of the beam; hence it is well to reflect that, considering the sea plane to be divided into two parts by the alignment, *the bow must be toward the side away from the enemy when he is to be brought to bear abaft the beam, and toward the side next to the enemy if he is to be brought to bear forward of the beam.*

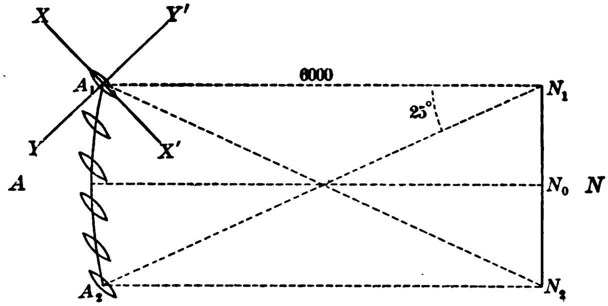

FIG. 38.

Let us now consider what may be the situation of the party A from a defensive point of view. In order to fix the idea, let us suppose that the party N is also in the fundamental position, but in column of vessels; and that the distance is 6000 meters.

The A party will possibly concentrate the fire on N_1 or on N_2; and if, as is customary, we refer to an alignment of six ships at intervals of 500 meters, the ship for concentration will receive the offense in a sector of about 25° *couting from the beam.*

This being the case, let us suppose that the ships of the A party have sectors of maximum offense with amplitudes of 45° forward of and abaft the beam; if N concentrates his fire upon A_1, that ship will receive the offense in a sector included between directions

* In referring to the longitudinal axis we consider indifferently the hypothesis that N_1 is kept forward of the beam, or that it is kept bearing abaft the beam. (Author's note.)

that form angles of from 20° to 45° *with the longitudinal axis;* if, however, the fire is concentrated upon A_2, that ship receives the offense between directions that form angles of from 20° to 45° *with the beam.* This example suffices to show that it may be advantageous to present the ships inclined to the alignment; the more so as, within the limits of distance at which it is specially advisable to concentrate the fire (section 14), the angle $A_1N_1A_2$ will have a value smaller than the one under consideration.

In case of the distribution of the fire it is seen a fortiori *that it may be advantageous to present the ships inclined so that each ship may have its corresponding adversary bearing in a direction of maximum utilization.*

It is to be noted that, when the A ships have sectors of maximum offense that extend 60° forward of and abaft the beam, if the regulator ship has N_1 bearing in a limit direction of a sector of maximum offense—that is to say, only 30° from the longitudinal axis—it is possible that some ships will be exposed to enfilading fire; which presents no disadvantages at the maximum firing distances (as is said in Chapter I, Part I), but is ordinarily to be avoided. Hence it may generally be established that *the polar bearing on which the regulator ship keeps the nearest enemy's ship by sight vane, must bear some relation to the way in which the enemy's alignment is inclined to the line joining the centers, as well as some relation to the criteria concerning the direction of maximum utilization.*

61. *Evolutions in Simple Alignment.*—For offensive contact we have established the necessity of having as little recourse as possible to evolutions; without, however, excluding the possibility of being obliged to do so in case one cannot succeed in keeping the alignment in a position sufficiently near the fundamental position.

As has already been noted (section 58), the proper methods for changing the alignment are limited to that performed in succession and those based upon wheeling the column of vessels. *In general, it is well to give the preference to the first method on account of its greater simplicity, and, owing to the possibility of changing an evolution in progress, adapting it to the counter movement of the enemy.* It results from this that the other methods abovementioned can usefully be employed in particular cases, when it may be expected to secure with them the desired objects in a considerably shorter time than would be required by

the evolution performed in succession; and this without too greatly disturbing the firing.

In executing the wheel with the speed ratio $\frac{1}{2}$ conformably to the conclusions of section 33, IV, in order to have an advantage in rapidity over the evolution performed in succession, the angle ω, through which it is desired to change the alignment, must be less than 30°, or than 60° according as the pivot is the rear ship or the leading ship. When pivoting on the ship about one-third from the head of the column—as results from the table in section 53—there is also an advantage in rapidity when ω reaches 90°.

From what has been said in this chapter, the ships will generally be inclined to the alignment. The evolution of section 53, II (which can be executed by pivoting on the rear ship or on the leading ship) permits of forming a column of vessels inclined at the angle ω to the actual alignment, without need of changing course together on the said actual alignment in order afterward to execute the wheel.

If the angle ω is within the limits above recorded, *and if the course is sufficiently near the one required for the evolution, within a limit such as to permit one to expect but little disturbance to the firing,* the evolution, pivoting on the rear ship, is advisable if the course inclines toward the new alignment, or on the leading ship if the course inclines in the opposite direction. In other words, if α is the polar bearing of the formation, it is necessary that the difference $\phi_c - \alpha$, or the other difference $\alpha - \phi_t$, be sufficiently small; ϕ_c and ϕ_t indicating, as usual, the angles corresponding to ω given in the table for wheeling the column.

When the circumstances just mentioned are not realized, the course may be changed on the alignment, thus resulting in a column of vessels, and the wheel executed afterwards, pivoting at about one-third from the head of the column; in this way a gain in rapidity may be had, but the situation will often counsel its abandonment because the said advantage will be negligible when compared to the inconvenience resulting therefrom. The English writer several times cited expresses himself in this connection in the following manner: "Wheeling a column of vessels is undoubtedly an efficacious method of changing the direction of a long line in the quickest way possible; but reflecting upon the disorganization that such a change brings upon the firing of a squadron, it must be used with extreme caution."

Moreover, in prescribing the angle through which the alignment

is to be changed by wheeling, it is necessary to keep in mind the probable counter-movement of the enemy; not taking this into account, there might be attributed to the methods by wheeling a greater importance than they really have; while, in practice, such importance is very limited.

We propose to fix these ideas by considering how such illusions may arise.

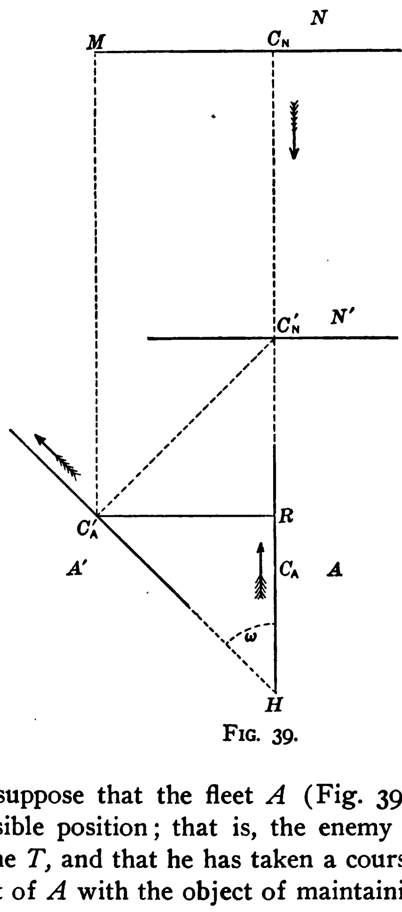

FIG. 39.

Let us suppose that the fleet A (Fig. 39) finds itself in the worst possible position; that is, the enemy N has succeeded in crossing the T, and that he has taken a course parallel and opposite to that of A with the object of maintaining his advantage of position and drawing the maximum profit therefrom by diminishing the distance. Let us indicate the speed of the A party by V_A. If this party wheels his alignment through ω, pivoting on the rear vessel, the new inclination Ω of A's alignment to the line joining the centers is greater than ω. We have already called attention to

this in section 53 and observed that in contact out of range the difference $\Omega - \omega$ is of small importance; but it is understood that if the distance diminishes beyond a certain limit, the angle Ω may become about $90°$, ω still being within the limits before mentioned. Let us seek the conditions of distance necessary in order that we may have $\Omega = 90°$.

Let S be the length of A's alignment, and let us, as usual, indicate by t, the duration of the wheel on the rear ship, and by t_0 the length of time that would be required by an evolution in succession; that is to say, let

$$t_0 = \frac{S}{V_A}.$$

If C_A' is the new position of A's center, and H is the initial position of the rear ship, since, during the evolution, the track of the pivot ship is $\frac{1}{2}V_A t_2$, we obtain

$$HC_A' = \frac{1}{2}V_A t_2 + \frac{1}{2}S.$$

When there is realized the condition $t_2 \leqq t_0$ (which by the table in section 33 corresponds to $\omega \leqq 45°$), we then have

$$HC_A' \leqq S.$$

When $\omega \leqq 45°$, in the triangle $HC_A'C_N'$ (in which C_N' indicates the position of N's center simultaneous with the position C_A'), we have

$$C_A' C_N' \leqq HC_A',$$

or

$$C_A'C_N' \leqq S.$$

In order that A may secure an advantage of position within the limits established for ω for a wheel on the rear ship, it is necessary that the distance between the centers at the end of the evolution be less than the length of the alignment; *and that the course of the party N be kept unchanged.*

Given that the distance is within such limits as not to exclude the possibility that A may attain his object, if the party N answers by making a simultaneous change of course so as to move in the same direction in which A executes the wheel, thus bringing itself into column of vessels, the party A, at the end of the evolution, will find itself in a situation very different from the one imagined. In fact, setting aside for both the adversaries the time required for the changes of direction, let us suppose that N's change of direc-

tion is made at the same instant at which A begins the wheel; the party N, at the end of the time t_2, would again be in fundamental position when its center should arrive at a point M, such that $C_N M C_A' = 90°$. Now, drawing $C_A'R$ parallel to $C_N M$, from the right-angled triangle $C_A'RH$, which is right angled at R, we have

$$RC_A' = C_N M = HC_A' \sin \omega.$$

As has already been noted, to $\omega = 45°$, there would correspond $t_2 = t_0$ and $HC_A' = S$; in such case we should have

$$C_N M = S \sin 45° = 0.7S,$$

and hence the speed V_N necessary to allow C_N to arrive at M when the center of A reaches C_A' would be given by

$$V_N t_0 = 0.7S,$$

or

$$V_N = 0.7V_A.$$

When $\omega < 45°$ a smaller value of V_N than this would be sufficient; this shows that, *although the counter-move of N may not* be immediate, if the party N possesses a speed about equal to that of the enemy, this speed will be sufficient to permit C_N to arrive on the line $C_A'M$ and even to pass beyond it. So, then, at the end of the abovementioned wheel the party A might be in a relative position so different from the one prognosticated as to render another evolution necessary. In order not to run such risk the amplitude ω of the wheel should evidently be 90°, and the pivot should be on the ship at one-third from the head of the column. But it is also well to reflect that, besides the evolutionary rapidity, it is important, as regards the advantages of position, not to change the alignment any more than is necessary; for this reason, everything considered, it seems that in the case in question the evolution performed in succession would be preferable for A, unless the extreme ships are very swift.

As is well known, in simultaneous changes of direction, every ship must wait for the movement to be begun by the adjacent inner ship on the side toward which the change is made; for this reason the changes of direction that are called simultaneous are practically successive changes at very short intervals of time. Conformably to this, in order to execute such changes with the maximum promptness, it is to be borne in mind that the inner

ship on the side toward which the change is made can haul down the signal and begin the movement as soon as the signal is repeated by the adjacent ship.

A particular case worthy of consideration is that of a fleet in column of vessels that desires rapidly to invert the course. It is not impossible that this may be required in order to stop an abrupt movement of the enemy, as happened to the Japanese at the battle of Tsushima. In such case the simultaneous change of direction would contemporaneously disorganize the firing of the whole fleet; therefore, the example of Togo is to be imitated by making the ships of each division change together, and the divisions change in succession so that, during the movement, one division remains protecting the other with its fire.

62. *T Positions.*—To the criteria established for the conduct of a fleet in a simple alignment in offensive contact it is well to add a few observations directly regarding the object that the maneuver must have in view.

I. It is incontrovertible that the ideal object would be that of crossing the *T;* but with two compact fleets it is obvious that this cannot be accomplished, no matter how small the maneuvering qualities of the enemy may be. Therefore, it is not necessary to sacrifice the maneuvering in the least in order to tend toward this ideal. The *immediate* tactical situation must be kept in view, seeking above everything else to maintain oneself in fundamental position while still tending toward crossing the *T*. Very small importance should then be attributed to the study of maneuvers based upon a preconception of passive conduct on the part of the enemy. Let us give an example of this.

Supposing two adversaries in column of vessels, if one of them keeps the course unchanged, then the other, possessing greater speed and his column leader steering with a certain sight-vane angle, can reach a sector of minimum offense of the enemy's fleet. Given the speed ratio and the limits within which it is desired to keep the variation of the distance, the opportune sight-vane angle might be graphically deduced and the various angles afterwards registered in a table, the practical importance of which we may value with the following consideration.

It is not impossible that, by concentrating the fire on the leading ship of the enemy's line, we may deprive the said line of its chief; for this it would be necessary that the flagship initially lead the line; that, the commander-in-chief being dead, the signal trans-

ferring the command be not seen; and that the commander of the leading ship, being without orders, should keep the course unchanged, as happened at the battle of August 10, 1904. But this is a very particular case, and it is logical to believe that the enemy will so act as to avoid it, considering this hypothesis to be among those generally prescribed for tactical contact. Then, the maneuvering commenced with the sight-vane angle supplied by the table would not answer to any rational conception; rather, it is easy to believe that the table would be a useless shackle, even in case the enemy should behave in the aforesaid passive manner, because, the maneuvers inspired by the criteria generally admitted in the preceding sections would answer better.

II. From what has been said in the preceding chapter (section 56), it is to be predicted that, at the beginning of offensive contact, the positions of the two adversaries will not be tactically equivalent; it is even not illogical to affirm that, while generally excluding the probability—as has just been observed—that the ideal crossing of the *T* may be completely secured, it will be at the initial moment that it will be possible to approach that ideal.

In order to fix the idea, let us note that, at Tsushima, the fleet of Togo, finding itself forward of the enemy's beam at the moment of sighting him, if it had steered on a line of bearing directly on the course of the latter, it would presumably have been able to establish offensive contact in a more predominant position than the one obtained with the inclined course and with the formation in column of vessels.

So, then, the example of the preceding section shows that if one of the adversaries is in an advantageous position, the evolution of the enemy intended to establish superiority or at least tactical equivalence, will hardly completely attain its object, it being very easy to execute the counter-movement to such an evolution; on the contrary, if instead of supposing—as in the said example—that the party *N*, after having crossed the *T*, has taken a course parallel to that of *A*, we imagine that it maneuvers according to the criteria deduced in section 59, the counter-movement to *A*'s evolution might not always be necessary. In such case it is true that *A* might succeed in assuming an equivalent alignment; nevertheless, even when this is reached, the ships of *A*, being in column of vessels, will not find themselves in the best defensive conditions, and it will still remain to them to execute a simultaneous change of direction, with disturbance to the firing, in order effectively to

establish conditions of equivalence; while the ships of N will have been all the time in the best possible conditions from the offensive and defensive points of view. For this reason, and on account of the difficulty of properly estimating the variability of the tactical situation during the evolution, it is to be presumed that some portion of an advantage of position will always remain; and if we bear in mind, as already noted in section 25, that the advantages obtained produce a compound effect, that victory is the integration of small advantages, each one of which, separately considered, might seem negligible, we must recognize *the great importance to be attributed to the initial tactical situation.*

III. Having had the good fortune to cross the T, in order to maintain the relative position with respect to the enemy, it is necessary to change to a parallel course; but it seems logical to limit this rule to cases in which its application does not imply a sacrifice of offensive power. In fact it is not presumable that the enemy will not maneuver to extricate himself from his critical position, and hence, proposing to oneself the object of maintaining the position with a sacrifice of offensive power, although the latter may prove to be all sufficient, would seem to be aiming at an illusory object, to obtain which one will find himself obliged to execute two changes of course at very short intervals of time. Thus, having crossed the T with respect to a fleet in column of vessels, if one were to change his course, one-half of his principal armament would quickly go out of action. Let us suppose further that in this way one might remain in the advantageous position for a time double that which would remain to him when developing the maximum offensive power; the minor duration of the advantage would be compensated in the second case by the greater total result. For the rest, under the wild hypothesis that the enemy does not maneuver, one might keep himself in the sector of minimum offense of the enemy's alignment, still developing the maximum intensity of fire; indeed, it would suffice to execute an opportune change of course on arriving in proximity to the limit of the aforesaid sector.

63. *Maneuvering on a Double Alignment.*—It is well known that the experiments carried out in France with the already mentioned Fournier system of tactics, have brought to light the inconveniences of the double alignment in offensive contact.

The illustrious admiral proposed to himself, by dividing the fleet into tactical units each formed by three ships, to obtain great

manageability by virtue of the shortening of the line. For this purpose, the group-leading ships, as well as the units composing such groups, must not be held rigidly bound to the formation, but must move opportunely on their own initiative in order to secure the best utilization of the guns. Nevertheless, in practice, the ships of the outer line, obliged to fire at targets that present themselves between friendly ships, cannot always be in the desired position; *frequent changes of the target constitute the inevitable inconvenience of the double alignment.*

On the other hand, in the preceding chapter (section 55), it has been made evident that such a form of alignment has scant evolutionary capacity; or, the manageability deriving from the shortening of the line is only apparent. In order to tend toward this object it might be prescribed that the distance between ships could be shorter than that held to be necessary for the simple alignment; but there would then result a limitation of the movements, it being necessary to abandon simultaneous changes of course; and the anxieties of maneuvering would be increased.

Finally, as we have already noted in Chapter II of Part I (section 11), the launching of torpedoes for the maximum run against a fleet, while it is not rational if the enemy's alignment is a simple one, may have a probability of success against a fleet in two lines.

For these reasons we hold that, unless we have a very numerous fleet, the adoption of the double alignment is to be restricted to cases in which we ought to utilize in the second line any antiquated ships, limiting their number, however, as is set down in section 56.

64. *Maneuvering by Independent Groups.*—Let us suppose a fleet broken up into groups each one of which has a speed not inferior to that of the enemy's fleet; that is to say, the condition recognized in section 57 as necessary for obtaining a good initial situation is satisfied.

It is true, as we noted in section 20, that the compact fleet, by assuming an opportune angular alignment, may bring itself into conditions of equivalence with respect to the enemy that is divided into groups; it is obvious, however, that, in practice, it will not succeed in obtaining these conditions continuously, because the divisions of the compact fleet cannot always satisfy the double condition of keeping together, and having, each one of them, an alignment in fundamental position with respect to the corresponding group of the enemy, besides having the ships in-

clined to the alignment in a way suitable for the development of the maximum offensive power. The tactical government of the compact fleet will have to satisfy too many conditions, owing to which the said compact fleet will be notably a poorer maneuverer than the enemy.

The advantage of maneuvering by groups being derived from this idea, it is clear that such advantage will be maximum when one of the groups is composed of a few ships (not more than six) endowed with very high speed. The maneuvering of this division, called the *flying squadron,* must be developed in a way such as to produce the maximum rapidity of rotation of the line joining it with the adversary; then it is to be presumed that it can enter a sector of maximum offense.

The number of ships of the flying squadron having to be limited, as has just been said, it appears to be clear that it is important that each of these ships should have a powerful armament. The type adapted to such a purpose is then that of a very swift armored ship, with a speed of at least four or five knots greater than the types that are constructed for composing the principal squadrons, with a powerful armament, and with the best protection possible subordinately to the development of the offensive capacity and the mobility.

From what has already been established, the flying squadron must generally be kept at the same distance from the enemy as the principal squadron; but when the distance falls near to the lower limit of the mean distance (3500 meters) a closing in maneuver by the flying squadron is not to be deemed rash, trusting that if the enemy commits the error of maneuvering to engage with the said group, he will place himself in conditions of inferiority with the opposing principal squadron. If, on the other hand, this were attempted at a greater distance, given the time that would be required for a considerable approach, the flying squadron would risk being overpowered.

Conformably to what we have set forth in section 62, III, the flying squadron must not sacrifice the development of the maximum offensive power to the maintenance of a *T* position.

65. *Maneuvering at Close Quarters.*—We now propose to see how the criteria established in section 46 for the maneuvering of a single ship within the limits of a fight at close quarters may be extended to a fleet of ships. Even if, as is to be presumed, the

two adversaries do not maneuver with the principal object of ramming, they must run to meet each other.

For convenience of reasoning, let us begin by considering the hypothesis that a group composed of several ships is fighting an isolated ship; and let us ask ourselves the following question: Given that the ships of the group desire to ram the enemy's ship, what could be the formation and the most opportune maneuver?

Let us observe that it would be exceedingly dangerous for the ships of the group to execute a maneuver which might have for its object the concentration of the rams; we mean by this that if, for example, the ships of the group are two, *A* and *B*, disposed in line abreast, and if the enemy's ship *C* steers for the center of their formation, the two ships *A* and *B* cannot attempt simultaneously to ram *C* without risking ramming each other. In other words, *A*, for example, can head for *C*, and *B* must change course parallel to *A*; while *C*, in so far as the ram is concerned, will in this way have to do with but one ship.

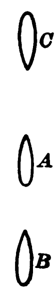

FIG. 40.

This simple fact must be kept in mind because it shows that any maneuver based upon the concentration of the rams must be abandoned; and that, instead, for the employment of these weapons, it is necessary to base it on successive action. In order that the action may assume this second form, the formation of the group must needs be a deep one; *consequently the column of vessels may be considered as the fundamental position.*

The column leader of the group steers for the enemy's ship; the two ships pass close to each other; the second ship in the line maneuvers with respect to the enemy without troubling itself to follow the column leader in succession, and so on.

It is here necessary to observe that the conditions of the ship that fights with the group grow worse the greater is the depth of the latter's formation, up to a certain limit. With this we desire to refer, not only to the greater number of ships that successively attempt to ram, but also to the offensive returns of the same. Since, indeed, within the limit of their close approach, each ship has the maximum interest in keeping the bow on the enemy, the ship *A* (Fig. 40), after passing *C*, turns with the helm hard over so as to come again to a meeting with *C;* and, analogously, *C* would wish to turn also, but cannot do so on account of *B*, who imitates the maneuver performed by *A*. The ship *C* is hence

prevented from inverting the course, and consequently finds itself in a condition of grave inferiority with respect to *A*, unless it has more speed or possesses better evolutionary qualities. The group is so much the better disposed for this purpose the more the depth of its formation approaches that necessary for giving *A* a notable advantage with respect to *C* in the inversion of the course. It is understood that in increasing the depth of formation beyond a certain limit, the advantage ceases to exist.

Passing from the particular case considered to the more general one of two groups on the basis of the ram only, it results from this that a group that moves in line abreast against another in a formation nearly approaching that of a column of vessels, is in an inferior position; it suffices that the ships of the latter group be not bound to maintain the formation, but may consider it only as a basis for the maneuvering.

Let us now see what conclusions may be reached in relation to the employment of the torpedo. We begin as usual with considering the hypothesis of a group of ships that attack a single enemy's ship; both the adversaries are supposed to be armed with lateral launching tubes.

It is easily seen that the group must do its best to have its own ships pass successively on the same side of the enemy. As a matter of fact, if the group is composed of two ships, it will be able to use its torpedoes as well if the enemy's ship passes between the ships of the group, as if it leaves them both on the same hand; but in the first case (which is that in which the ships of the group are not in column of vessels) the group permits the enemy to put forth his maximum offense by launching torpedoes from both sides. For this reason it is obvious that the first method of action is preferable, even when the ships of the group are more than two.

At this point the object of the maneuvering of the group appears to be thus determined: *To pass by on the same side of the enemy's ship.* The maneuvers should then be about that in column of vessels and in succession. Inversely, the ship that fights the aforesaid group should maneuver so as to pass between the ships of that group.

Let us now suppose the two groups to be equally armed with torpedoes, and let us imagine that the first has a front formation, and the other a deep formation. For example, let four be the number of ships composing each group, and let us indicate by

A, B, C, D (Fig. 41) the ships of the first group, and by A_1, B_1, C_1, D_1, those of the second.

If, in order to consider a special hypothesis, we imagine the first group to be formed in a square and the second in column of vessels, as shown in the figure, it is evident that, as regards the torpedo, the group A_1, B_1, C_1, D_1, during the passage by, will be in better conditions than the other, because it can fire twice the number of torpedoes.

As the same reasoning might be repeated for formations analogous to those considered, we may affirm that the object of the maneuver in battle at close quarters, must, with regard to the use of the torpedo, be that of obliging the enemy's ships always to present the same side in passing by; and inversely, each ship, bearing in mind the object just mentioned, must seek to pass between the enemy's ships so as to launch the greater number of torpedoes.

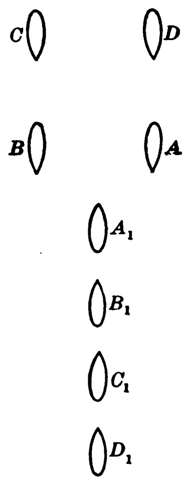

FIG. 41.

It results from the foregoing that the maneuver for the employment of the torpedo in battle at close quarters harmonizes with what is necessary for the possibility of ramming.

Let us now place what we have set forth in its relation to the employment of the guns.

It being admitted that, within a certain limit of distance, the adversaries must steer for each other, it is well to consider this necessity in connection with the other necessity of firing with the maximum number of guns permitted by the development of the action; consequently, while in long-range battle, a ship has to keep the enemy bearing in a sector of maximum offense, inside of the aforesaid limit it would be in a position which permits of firing in the direction of the bow. Not only does the line abreast satisfy this condition, but also any other formation in a straight or curved line which permits the ships to fire ahead.

Summing up, we may note that, considering the three weapons together, the best arrangement for the ships in battle at close quarters is that which permits the simultaneous employment of the forward guns, and differs as little as possible from the column of vessels; in other words, it is a question of a line of bearing that makes a small angle with the direction of the course.

In steering for battle at close quarters the ships of each group must hence take, by prompt formation (any other method is evidently impossible), the aforesaid position with respect to the most advanced ship in the direction of the course; doubtless the distance between ships will not be the same, and, in fact, the formation will differ in practice from a line of bearing; but there is no need to trouble about that. In effect, it is sufficient for the ships to be echeloned on the side that possibly will be indicated by the admiral, or that the situation with respect to the enemy shows to be opportune.

Each ship of the group, after passing by the enemy, must naturally invert the course in order to run again upon him, unless it is prevented from making such a movement by the quick arrival at short distance of the enemy's ships. This inversion of the course presents no dangers of collision with friendly forces if the ships are sufficiently echeloned in depth and the opportune side is perfectly indicated, it being naturally the same toward which the leading ship has turned.

If the battle at close quarters, instead of taking place between two single groups, is general, according to the foregoing a party moves toward it with the single groups following each other, possibly toward the same part of the enemy, so as to obtain the concentration of forces.

CHAPTER V.

TORPEDO-BOAT MANEUVERS.

66. *Characteristic Conditions of the Attack of Torpedo-Boats.* —In the study of the maneuvers of ships opposing each other we have logically held that at all times each of the adversaries seeks to maneuver opportunely; but the essential characteristics of the nocturnal attack of torpedo-boats are surprise and high speed; hence we do not reason in an entirely aprioristic way when supposing that while the torpedo boats execute the maneuver of approach, the ship attacked continues on her course. It would, however, be erroneous to deduce from this that the maneuvering reduces itself to solving a simple problem in kinematics; indeed it is necessary to keep in mind the conditions of extreme uncertainty that are realized in practice. With the assistance of Daveluy (*op. cit.*) let us fix our thoughts upon the difficulties that a torpedo-boat encounters in attacking a ship in motion.

The enemy is sighted in the form of a black mass. The torpedo-boat must take account of the direction in which its objective is moving, and then gain an advantageous position for the maneuver of approach; that is to say, a position from which, steering to arrive at launching distance, there may be assured to the torpedo a convenient angle of impact.

This is very easy to define but very difficult to realize. When, on sighting the ships, one is not in the aforesaid advantageous position, in order to gain it one risks losing the benefit of the surprise; and for the rest, it is not easy to know whether one is or is not in an advantageous position; one is led by this to steer to approach the enemy's mass, which is hardly distinguishable, reserving it to himself to maneuver afterwards as he may.

In general, then, we cannot succeed in solving the problem of approach in a theoretically exact manner; moreover, when we have taken account of the direction in which the enemy is moving, we still shall not have succeeded in estimating his speed, nor may

we rely upon making this estimate in time; which would be necessary in order to construct the triangle for launching the torpedo.

From such conditions of uncertainty results *the necessity of launching from a very short distance.* The improvements made in the torpedo are to be considered as important, not because they give the means of launching, for example, at 1000 meters instead of 500, but because they confer upon the torpedo launched at the latter distance a higher speed than it had before, and hence a greater probability of hitting.

The results obtained by the Japanese torpedo-boats after the battle of Tsushima did not depend alone upon the fact that the artillery battle had deprived the surviving Russian ships of a part of their means of defense, but were due to the close and vigorous manner in which the attacks were conducted. Togo, in his report of the battle, expresses himself in this connection in the following words: "According to information gathered from the prisoners, the attacks of the torpedo-boats during the night were extraordinarily impetuous. They hurled themselves at such speed and approached so rapidly that it was impossible to stop them; they came so close that the guns of the ship could not be sufficiently depressed in order to hit them."

While it is necessary to remember that the real conditions of the torpedo-boat attack will be those just mentioned, this does not exclude the advisability of reflecting upon the theoretical conditions of the maneuvering, considering them as the limit toward which we must tend. The general criterion of launching from a short distance being established, in the following reflections we shall hold that the run c to be considered as normal for the torpedo in a night attack of torpedo-boats is that of 500 meters.

67. *Maneuver of Approach.*—It is well known that the rules which practically apply for the maneuver of approach can be formulated as follows: 1st. If the torpedo-boat finds itself to one side of the ship, it must steer as if it desired to meet that ship (section 32, I) (lateral attack). 2d If the torpedo-boat finds itself almost exactly ahead of the ship, in approaching it should move somewhat to one side, and afterwards steer a course opposite that of the ship (attack in passing on opposite courses). When the torpedo-boat sights the ship in a stern sector, since the lateral attack would be too long, it must first, without approaching so as

to be seen by the enemy, gain a convenient bearing and then maneuver as in the first case.

We do not desire to create complications by seeking for different rules, but we propose to fix our minds on the rules alluded to; observing that, from what we have set forth in section 32, their theoretical exactness might be placed in doubt; and we now wish to demonstrate that these rules are very nearly exact.

1st. If V_N is the speed of the ship N that it is desired to attack, and v is the speed of the torpedo, as we have already had occasion to note in section 9, the geometrical locus of the positions from which the launching may be executed in such a way that the torpedo may strike the ship after a run c is obtained by making NN_1 (Fig. 42) equal to $c \frac{V_N}{v}$, describing a circle with a center at N_1 and with a radius c, and then limiting to right and left of the ships the arcs—as SS'—included between the straight lines, passing through N_1, that form angles of 30° with the course.

The theoretically exact maneuver for the approach would then be the one for arriving on the arc SS' in the shortest possible time. Setting aside the angle of impact, the problem of kinematics is that of bringing oneself in the minimum time to a distance c from the imaginary point N_1; and hence, if the maneuver could be executed with theoretical precision, from what we said in section 32, II, on arriving at launching distance in the shortest time, the torpedo-boat should find N_1 in the direction of its bow. In other words, the maneuver of approach should be executed in such fashion that, if the torpedo-boat had a bow launching tube, on arriving at launching distance it should have no need of changing direction in order to execute the said launching. We note

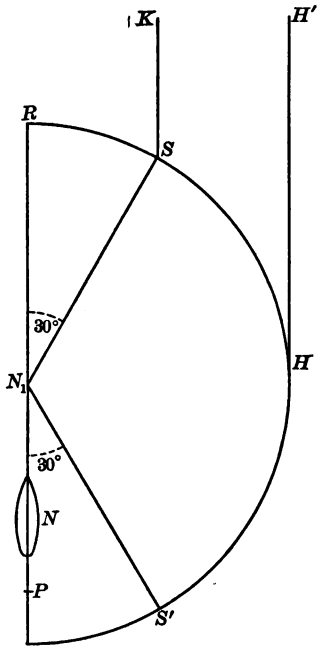

FIG. 42.

this circumstance in order to fix the idea, and not because we at-

tribute to it any special importance; the bow tube being generally abolished.

So, then, in order to arrive in the minimum time at the distance c from the imaginary point N_1, it would be necessary to maneuver (see section 32) as if it were desired to reach a point P, which is moving at a speed V_N, and situated astern of N_1 at a distance

$$N_1P = c\frac{V_N}{V_T},$$

V_T being the speed of the torpedo-boat.

On the basis of the value of NN_1, above mentioned, the point P is distant from N a length $NP = N_1P - N_1N = c\left(\frac{V_N}{V_T} - \frac{V_N}{v}\right)$.

Evidently the distance NP is very small; so, putting $\frac{V_N}{V_T} = 0.8$ and $\frac{V_N}{v} = 0.5$, we have

$$NP = 0.3c = 150 \text{ meters.}$$

We may hence conclude that, *besides being easily applied practically* (with the reservation mentioned in the preceding section), *the rule enunciated for the lateral attack is also very near to theoretical exactness.*

2d. Let us now suppose the torpedo-boat to be in the zone included between the courses HH' and SK, both of which are parallel to the course of N, and the first of which is tangent to the circle having a radius c and its center at N_1. It is readily seen that, if the torpedo-boat were to execute the maneuver of approach as if it wished to reach the point P or the center N of the ship, it might arrive at launching distance at some point of the arc SR, and hence would not be in a position for launching with a sufficient angle of impact. It results from this that the sure and simple maneuver, to which corresponds a rapidity of approach differing from the theoretical rapidity by a negligible quantity, consists in running with a course parallel and opposite to that of the ship attacked, *when the torpedo-boat, at the beginning of the maneuver of approach, judges itself to be laterally removed from the course of the ship by a distance included between c and ½c, or between 250 and 500 meters.*

3d. The following considerations are sufficient to show the necessity for the torpedo-boat to avail itself of its greater speed

in order to gain a position in a forward sector of the enemy's ship when the latter is not sighted from such a position.

The danger zone for a torpedo-boat is naturally that in which there is great probability of being hit by the guns without being able to launch a torpedo. Since we are referring to a night attack, the range of the anti-torpedo-boat guns—that is to say, the radius of the danger zone—may be held to be about 2000 meters; and it is to be noted that the distance at which the torpedo-boat sights the ship is often not greater than this. The inferior limit of the danger zone is constituted by the circle with its center at N_1 and the radius c (Fig. 42), which circle moves with the ship at a speed V_N.

So, then, it is clear that the further forward is the bearing on which the torpedo-boat begins the approach, the more rapidly will it traverse the danger zone, for two reasons: I. The relative speed being so much the greater, so much the more rapid will be the variation of the distance. II. So much the greater will be the distance at which the launching can be executed. It may be noted that in giving importance to this we are not in opposition to the criterion established—that of launching from a short distance. It is very true that we may not pretend to diminish the danger zone by launching the torpedo for a long run, because in so doing we should obey a mistaken defensive sentiment, and we should risk rendering our offense inefficacious. The torpedo-boat that thinks of protecting itself instead of attacking vigorously is a torpedo-boat lost without having accomplished anything. But in the case under discussion the situation is different; the term *short distance* must be precisely understood in the sense of *a short run for the torpedo;* and the further forward (up to the line SK) is the position of the torpedo-boat, so much the more may we launch from a distance, the run of the torpedo remaining as short as has been established, without having a notable difference in the probability of hitting.

68. *The Maneuvering of a Flotilla of Torpedo-Boats.*—Owing to the characteristic difficulties of the torpedo-boat attack pointed out in section 66, it is necessary that the attack be executed by a certain number of units; there being thus the possibility of producing uncertainty in the firing of the enemy, who is obliged to distribute his offense among the different targets; and permitting the hope that the number may remedy the scant probability of

individual success. Nevertheless, as Commander Vannutelli has observed (*Rivista Marittima* for May, 1910), it is well to consider the following axioms:

1st. The probabilities that the torpedo-boats will be hit before arriving at launching distance increase with the compactness of the order of attack; since, when the torpedo-boats are very close together, they constitute a single, extended target, easily visible; and, *vice versa,* they diminish with the increase in the dispersion of the torpedo-boats in the direction normal to the line of fire.

2d. The same probabilities increase with the increase in depth of the order of attack of the torpedo-boats in the direction of the bearing of the ship; that is, they are maximum when the various units keep on or near the same bearing from the ship, thus exposing themselves to raking fire. It results, therefore, that it is necessary for the torpedo-boats to have a suitable dispersion, and to arrive at the launching position simultaneously rather than successively.

But the length of the chord SH (Fig. 42) is equal to 500 meters, the angle SN_1H being 60°; we deduce therefrom that the maximum number of torpedo-boats that may *simultaneously* attack a ship from one and the same side, to the end that they may be properly separated, must be held to be *three.*

Having to aim at simultaneity of attack, the torpedo-boats of this group, in distancing themselves from each other for the execution of the maneuver of approach to the ship, must arrange themselves on an alignment normal to the line joining their center with N_1; thus also satisfying approximately the second of the axioms just enunciated. It can be established as a practical rule that the alignment may possibly be normal to the line joining its center with a point a little ahead of the ship to be attacked (the further ahead, the higher is the speed V_N).

From this alignment, the torpedo-boat occupying the central position may begin its maneuver of approach as if it were alone; and the others must follow a course parallel to it.

The action of one of these groups, which attacks the ship on one side, evidently favors the attack of a similar group on the opposite side, if this is made after a very short interval of time; since, from the moment in which it is discovered, it may be predicted that it will absorb practically all the attention of the enemy.

There is thus developed the advisability of constituting squad-

rons of torpedo-boats of six units, divided into two sections, destined to maneuver for the attack separately but co-ordinately.

Evidently, the attack of the sections on the two sides can be made on condition that the squadron, on sighting the ship, finds itself on the line of the course of the latter; otherwise the sections will attack successively; it may be presumed that the first attack, if it does not succeed, will be an efficacious preparation for the second; because, in the minutes following, there will be a relaxation of vigilance.

Such seem to be the guiding criteria, not excluding that it may be advisable to depart from them under special circumstances, in order to adapt oneself to the movements of the enemy, if he moves as the searchlights are directed, toward the number and position of the torpedo-boats illuminated.

The employment of several squadrons against a fleet of ships requires as a preliminary condition the envelopment of the enemy; that is to say, taking the position with the squadrons in different points of the horizon so that the adversary cannot withdraw from the attack. But it is needless to say that the problem of envelopment ought not to be considered a problem of kinematics; criteria for its solution cannot be pre-established, because the envelopment is to be held possible only when the adversary's fleet is occupied in an artillery battle. Typical conditions for a general attack are those described as follows in the already cited report of Togo: "Night was beginning to fall. Our torpedo-boat squadrons had already enveloped the enemy to the North, East and South. Consequently the principal squadron ceased fighting and withdrew at sunset."

69. *Tactical Action by Day.*—Let us recall to mind the beginning of the battle of August 10, 1904. The Russian squadron saw numerous torpedo-boats ahead, and, fearing that they might have thrown out blockading mines, changed course 90°. An action of such nature, which obliges the enemy to make a movement not required by the situation with respect to our battle forces, may be of great assistance to us.

A movement of destroyers directed so as to arrive at launching position may evidently be admitted against damaged ships, as was done at Tsushima against the *Souwaroff;* it may not be excluded with uninjured ships, on condition that the two principal fleets are not very far apart. Indeed, by day, the danger zone for torpedo-boats is so extended, and the fire of the medium artillery is so

precise, that the launching would have to be executed from a very long distance; and since, under such conditions, there is very scant probability of success, it is not worth while to expose the torpedo-vessels. When, however, the distance from the enemy is relatively short, that is, when, for example, the two fleets are fighting at close range, if nothing else is accomplished, the torpedo-boats will oblige a part of the enemy's ships to make a movement not required for its tactical employment with respect to the battle fleet; which may produce important consequences.

70. *The Maneuvering of a Submersible.*—A submersible, for an attack by day, finds itself in conditions analogous to those of a torpedo-boat in a night attack, with the added disadvantage of its inferiority in speed with respect to the ship. It must submerge at a distance of about three miles from the ship and steer for the approach; rectify the course by emerging the periscope, and then execute the launching. We propose to determine the sector in which the submersible should be found with respect to the ship at the moment of approach, in order that conditions making it impossible to arrive at launching position may not exist.

Let us suppose that the submersible executes the maneuver of approach according to the first rules indicated for a torpedo-boat; that is to say, it steers as if it wished to meet the ship.

Let a be the polar bearing we are seeking, or, the maximum angle that the ship-submersible joining line may make with the course of the ship in order to permit of approaching. Let us indicate by V_N and V_S the respective speeds of the ship and of the submersible, and, naturally, let V_N be greater than V_S.

From section 32, I, there results

$$\sin a = \frac{V_S}{V_N};$$

and hence for $\frac{V_S}{V_N} = \frac{8}{12}$, we have $a = 42°$; for $\frac{V}{V_N} = \frac{8}{16} = \frac{1}{2}$ we have $a = 30°$.

With the course of reasoning of section 67, in Fig. 42, we obtain

$$NP = c\left(\frac{V_N}{V_S} - \frac{V_N}{v}\right).$$

Making $\frac{V_N}{v} = 0.5$, we have:

$$\text{for } \frac{V_S}{V_N} = \frac{8}{12}, \quad NP = c;$$

$$\text{for } \frac{V_S}{V_N} = \frac{1}{2}, \quad NP = 1.5c.$$

The value of the distance NP is not, then, as small as in the case of a torpedo-boat; and this leads us to ask ourselves how much α may be considered as increased with respect to the values previously deduced, admitting—but not conceding—that the submersible might succeed in maneuvering in a theoretically exact way for arriving at launching position in the minimum time.

If α' is the polar bearing on which the submersible S would be seen from the point P in Fig. 42, the exact value of α is evidently that which corresponds to

$$\sin \alpha' = \frac{V_S}{V_N};$$

that is to say, there must be assigned to α' the values already deduced for α.

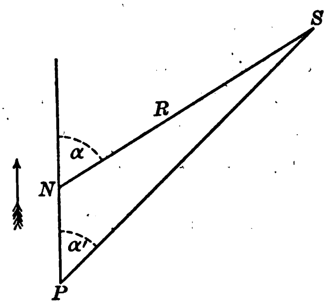

FIG. 43.

Indicating by R the distance NS (Fig. 43), at the beginning of the maneuver of approach, from the triangle NPS we have

$$\frac{NP}{R} = \frac{\sin(\alpha - \alpha')}{\sin \alpha'},$$

from which, substituting for NP and for $\sin \alpha'$ their values, we obtain:

$$\sin(\alpha - \alpha') = \frac{c}{R}\left(\frac{V_N}{V_S} - \frac{V_N}{v}\right)\frac{V_S}{V_N},$$

or

$$\sin(\alpha - \alpha') = \frac{c}{R}\left(1 - \frac{V_S}{v}\right).$$

For the two cases previously considered, the values of $\frac{V_S}{v}$ are respectively $\frac{1}{3}$ and $\frac{1}{4}$; introducing them into this formula, and putting $c = 1000$ meters and $R = 5000$ meters, we get:

$$\text{for } \frac{V_S}{V_N} = \frac{8}{12},\ \alpha - \alpha' = 8°;\ \text{and hence } \alpha = 50° \text{ (about)};$$

$$\text{for } \frac{V_S}{V_N} = \frac{1}{2},\ \alpha - \alpha' = 9°;\ \text{and hence } \alpha = 39° \text{ (about)}.$$

If, then, a submersible is signalled at a distance R from the ship, in order to prevent it from arriving at launching distance, it is

sufficient for the ship to change course through an angle that reaches the maximum values above mentioned.

This is not to be understood as denying the importance to which a submersible may rise—it seems to us that, under present conditions, we may deduce that, instead of relying upon its own maneuvering, the submersible ought generally to wait for the enemy to pass within range; that is to say, ***lie in ambush.***

Let us express ourselves in the words with which an American writer closes an important paper on the subject.* "The submersible is a slow and clumsy animal, but its bite is mortal. Keep out of its way. In any case it is not as likely to get you as we have been led to believe."

* PROCEEDINGS OF U. S. NAVAL INSTITUTE, Vol. XXXI.

PART III.

TACTICAL ACTION AS A WHOLE.

CHAPTER I.

Preparation for Tactical Contact.

71. *Route Formations.*—The route formation of the main body of the forces must be established with reference to the possibility of tactical contact with battleships and of attack by torpedo-boats.

As we have already had occasion to point out in section 38, one must bear in mind the necessity of not stretching out the ships of the line in chain; that is to say, they must be kept compact.

Like a fight at close quarters by day, so a night encounter between battleships will certainly not be desirable for the party that is the superior, owing to its interest in avoiding situations in which the unforeseeable is dominant; but it may be advisable for the one who desires to attempt a desperate stroke. It is necessary to guard against such an event, a constant rule being that of not supposing the enemy to be amenable to our designs. Consequently, in order to establish the criteria by which the route formation should be inspired, let us fix our minds on the modalities of the night encounter.

The struggle at close quarters can be its only efficacious form; for this the considerations set forth in section 65 are of value, according to which considerations the route formation must have as a basis the column of vessels, echeloning the ships from it according to the way in which the enemy presents himself. The considerations therein developed must be admitted *a fortiori*, because, naturally, by night, still more than by day, it is indispensable to reduce signals to a minimum and to avoid confusion.

We must hold with Labres (*op. cit.*) that the action of the two fleets will cease when they have passed each other, since a second encounter would imply an inversion of the courses, which must be excluded, owing to the difficulty of recognizing the ships of the two parties. But one must still put himself in condition to draw profit from the disorder of the enemy after passing him. For this

purpose it is well to dispose the forces in two divisions, with sufficient distance between them, so that they need not trouble themselves about the movements that, for each of them, may result from the encounters with the ships or the torpedo-boats of the enemy; these two divisions can then attack in succession.

In this way there is established *the advisability that the principal forces, if numerous, be divided at night into two divisions, rather than massed in a single assemblage.*

The route formation of each division in column of vessels is also the most opportune, having regard to the attacks of torpedo-boats. In fact it is well to observe that the maneuvering of the torpedo-boats will be directed toward executing the attack in such a way as to remain the shortest possible time under fire; therefore, the torpedo-boat will execute the attack upon the first ship that presents itself; and only in the improbable case that he may decide it to have been put out of action will he launch himself against the following ship.

Bearing in mind the characteristic conditions of the night attack of torpedo-boats (section 66), we must recognize that, practically, it is not possible for the torpedo-boats to make a choice of the objectives when the latter are composed—as we now suppose—of ships in motion. The route formation in column of vessels permits, then, the following advantages:

1st. The probability that the torpedo-boats may be in position to attack with opposite parallel courses is rendered minimum; and if this happens, the ships can fire ahead by moving freely out of the column of vessels and toward the opportune side as much as may be necessary.

2d. The maximum defense can be put forth against torpedo-boats sighted off the beam.

3d. The torpedo-boats are also placed in the worst conditions for the withdrawal after launching the torpedoes.

When cruising by night as well as by day in a zone in which the presence of numerous torpedo-boats is probable, aside from the measures for safety of which we shall speak, it must be deemed advisable to navigate at high speed. In fact, the higher the speed, the smaller—as is well known—is the probability of hitting with the torpedo, and the greater the difficulties for the torpedo-boats of executing the maneuver of approach under good conditions.

The cruising system just indicated is applicable, whatever may

be the conformation of the sheet of water that is being crossed. The relative positions of the groups are to be determined according to circumstances; such positions may vary from that in which one division follows the other at a distance, to that of two columns abreast with an interval between the columns of four or five miles; that is, which permits of putting the light artillery and the searchlights freely into action. It is naturally understood that the running lights are obscured, and that the searchlights must be put into action only when the presence of hostile torpedo-boats is signalled.

As Commander Sechi justly observes,* in employing the searchlights "to explore the horizon at more or less frequent intervals, one offers great facility to hostile torpedo-boats; because it is much more difficult for them to find the ships and make sure of their identity than to assail them after having discovered them."

The above-mentioned formation is the one that evidently serves best from the point of view of safety in navigation; it facilitates maneuvering and secrecy, enabling signals to be transmitted between the successive ships of each division by means of a flashlight, visible in a limited sector.

For communication between the two divisions of the naval force the best means of signalling seems to be that of wireless telegraphy, because any others might more easily serve to summon the enemy's torpedo-boats.

The question of the order in which the ships should open fire presents no difficulties with the adopted formation, each ship having a clear field of fire in case of lateral approach, and being easily able to echelon themselves in case of sighting the enemy in the direction of the course. The important thing is that the orders given to the units detached from the main body shall guarantee that the ships or torpedo-boats sighted are those of the enemy; if this necessity is satisfied it can be established that every ship shall open fire as soon as it sights the enemy.

By night as well as by day, the cruising order to be considered as normal for a section of torpedo-boats is that of a triangle of suitable shape, in order that one torpedo-boat may not be enveloped in the smoke of another. The triangular disposition confers the maximum safety in navigation, renders communication easy, avoids the elongations that are produced in the column of vessels, lends itself to the assumption of the opportune alignment

* *Elementi di Arte Militare Marittima,* Vol. II, page 420.

for the attack, and, finally, it permits of grouping in the minimum space, or it is adapted to keeping the torpedo-boats under the support of the ships.

It may be advisable for a flotilla to navigate with the two sections in formation different from that of a column, as Commander Vannutelli has proposed in the article already cited. "In column of vessels and with high speed, it is easy to lose contact, or, *vice versa*, to have dangerous closings in, especially when navigating with lights obscured; that is to say, when about a hundred meters of distance is enough for losing sight of the stern of the preceding torpedo-boat, while in lines abreast or oblique lines it is much more difficult to lose sight of the dark lines of the entire length of the adjacent torpedo-boat. Every one will remember the intense watchfulness and the continual variations of speed that the column of vessels requires by night, which, therefore, in a short time brings great fatigue. With frontal orders the squadron is presented well subdivided into two tactical groups, ready to separate for the opportune maneuver."

72. *Scouting.*—As is well known, we mean by *tactical exploration* that which is exercised by ships in direct communication with the main body, remaining in contact with it at a distance such as to permit a discreet reliance on being able to regain it when it passes to tactical contact with the enemy's battle forces. It is well for this reliance upon the reunion with the main body to be so much the greater, the greater is the tactical importance of the ships employed; that is to say, the greater the importance of these ships, the shorter should be their distance from the main body. Only in exceptional cases could it be desirable for the battleships to sight directly those of the enemy; thus, when in the Chino-Japanese War, Admiral Ito moved in search of the fleet of Ting at the mouth of the Yalu, he was not preceded by any ship, because he aimed at surprising the enemy. But he was able to rely upon the inertness of the Chinese; in general, however, it is presumable that the enemy will maintain a scouting service, especially if he is occupied in operations owing to which he might, by our unexpected arrival, be placed in a critical position; and then comes the necessity of being preceded by ships that will seek to repulse the enemy's cruisers, preventing them from establishing contact with our main body; that is to say, from comprehending the importance of the danger that menaces their fleet.

The importance of knowing beforehand of the approach of the enemy's fleet really exists, as we shall endeavor to show; but it is well to consider in what degree we may be able to satisfy it, if it cannot be presumed in what direction the enemy will be sighted. If we should pretend to form with the tactical scouts a continuous line about the main body, either we should have to employ many units, or the radius of the explored zone would be greatly restricted.

It results from this that tactical exploration, like strategic exploration, must have for its object the search for the main body of the enemy's forces, having regard, however, to certain limits of distance from one's own body. To the end that the warning may not be illusory, it is well to abandon the certainty that the scouts will encounter the enemy before the main body does so, and be content with only a probability. A lookout service tending to establish almost absolute safety over a sufficiently wide sector about the main body is, however, required *when the presence of numerous torpedo-boats can be expected in the sheet of water to be traversed.* In such service the vessels destined for tactical scouting assist; they constitute a first line of defense which, for the reasons mentioned, cannot be entirely relied upon; it is necessary, however, to guard oneself effectively, which can be done in the following manner, on the basis of the deductions of the preceding chapter:

Remembering that the torpedo-boats sighted astern are the least dangerous, it is necessary, by night, to have the naval force preceded and flanked by groups of torpedo-boats at a distance from the main body such that the searchlight of the ships may be operated upon occasion without illuminating them. Each section of torpedo-boats must cruise in compact formation in order to be ready to attack the enemy's forces that it may encounter. The greater cruising speed may be utilized by making these groups traverse a zig-zag with sides suitably inclined to the course of the main body. These torpedo-boats must signal the approach of those of the enemy and try to drive them back, without coming within range of the light guns of their own ships, since every ship must necessarily be able to fire upon any torpedo-boat that approaches it.

In order to exercise vigilance by day against submersibles, it is necessary for the destroyers to keep a lookout ahead and on each

side (up to about 45° from the course) extending themselves in chain. It would be desirable to have a chain at three miles and one at five miles; that is to say, within the limits at which the submersibles must begin the maneuver of approach.

73. *The Reconnoitering of the Adversaries.*—Although it may not be excluded, it is nevertheless not very probable that the fighting forces will sight each other directly; indeed, even admitting that only one of the hostile fleets carries out tactical scouting, when its scouts arrive in sight of the enemy, the latter will detach ships to drive them away, in order to prevent their maintaining the contact; and, as in the case wherein the scouting is carried on by both the adversaries, *an action between cruisers will precede the battle.*

It might be said that this statement is contrary to experience; the encounter between cruisers has not yet been produced, notwithstanding three successive wars; but we can easily give reasons why this may have been the case. For the Chino-Japanese War the consideration already advanced will serve; for the Hispano-American War, the battle took place between a division of four ships and a squadron that was blockading it, keeping with all its ships in close proximity to the entrance of the port. Finally, for the Russo-Japanese War, it is well known that the Japanese main body was constantly preceded by the cruisers; the battle of Tsushima would have begun as above stated if Rojestvensky had had the means of fighting the enemy's cruisers. But, as Semenoff observes in *Rassplata,* the Russian cruisers were either too weak or very old and with insufficient speed. "Furthermore, the admiral desired to save and keep all the elements together; the more so, since, the 12 armored ships being engaged with the 12 Japanese armored vessels, the cruisers would have had to protect the transports and engage by themselves all the rest of the Japanese fleet."

When the encounter between cruisers takes place, the party that has the greater strength in ships of this class, by obliging the enemy's cruisers to turn back, obtains the singular advantage of being able to regulate its own maneuvers of approach on the basis of information transmitted to it; while the enemy remains in uncertainty. In this way there is produced the situation that beyond dispute was realized at the beginning of the battle of Tsushima. Togo, after having stated that his cruisers reconnoitered the enemy without difficulty, adds the following: "These

divisions, although cannonaded from time to time by the enemy, succeeded in preserving the contact, sending by telegraph frequent and precise news concerning his position. And thus, notwithstanding a thick fog that did not permit of seeing further than five miles, we were able to know the position of the enemy, although he was 30 or 40 miles away, as exactly as if we had seen him with our own eyes. . . . . It was thus possible for me to make the dispositions for finding myself at about 2 o'clock near Okinoshima and to attack the head of the column on the port side."

The development of an action of growing importance between the cruisers will induce the main body to detach a sufficient force to complete the *reconnoissance.* In order to fix in our minds how this may happen, let us make use of an example.

A scout has sighted a ship; it moves to observe it and informs the nearest friendly ships of it by wireless telegraph, which ships transmit the news to the commander-in-chief. The suspected ship also has headed toward our scout, so that the recognition is quickly accomplished; the vessel sighted is a protected cruiser of the enemy, weaker than our own, and, consequently, at a distance of not less than 7000 meters it turns to run. The commander-in-chief does not consider this of sufficient importance to alter the course of the main body. The chase of the cruiser continues for some time and our ship gains upon the enemy, so that there is hope of making a good stroke.

A few ineffectual shots have already been exchanged by the two ships, when suspected ships appear upon the horizon, and very soon they are seen to be enemies. It is now the turn of our cruiser to run. It is is well to mention that when our cruiser was increasing its distance from the main body, another ship was moving so as to maintain a chain with it for the transmission of news. When the new enemy's ships are reported, there is then on our part a concentration of a division of protected cruisers in the direction of the adversary; thus we have again a preponderating force and the enemy again turns to run. The course of the main body is somewhat inclined in that direction and the appearance of new ships on the horizon decides us to effect a reconnoissance; that is, to determine if there are other principal forces of the enemy at hand besides those sighted. For this purpose it is determined to send out toward the adversary forces that will not be obliged to

give way except before the enemy's main body; in other words, the armored cruisers are sent forward at that time, at full speed, and the battleships follow ready to support them. The appearance on the horizon of a new division of the enemy still further confirms the idea that important forces are to be found in that direction, and, indeed, in the new division, we recognize the enemy's armored cruisers. The inferiority of the enemy in ships of this type is not slow in producing its effect; the adversary, in order not to be beaten in detail, must turn back and seek the protection of his battleships, that are sighted a little afterward. The object of the reconnoissance is attained; our ships take up a course parallel to that of the enemy and at his speed, signalling to the commander-in-chief the composition and the formation of the enemy's force; our admiral is thus in condition to make the necessary arrangements for attacking the enemy in the most opportune way, or to reverse the course if he does not wish to accept battle. Then begins the contact out of range.

CHAPTER II.

THE BATTLE.

74. *The Importance and Character of Naval Battle.*—As Makaroff writes, "the loss of ten ships in as many combats has not the moral effect of the loss of a squadron, although the number of ships lost may not reach ten."

The destruction of the enemy's movable forces constitutes the essential object at which we must constantly aim; pretending to secure the object of the war by avoiding battle between the forces and seeking secondary objectives is shown by history and deductive reasoning to be entirely erroneous; to us Italians it brought forth Lissa. *A battle desired is greatly preferable to a battle submitted to.*

These axioms, that should be taken as the basis for the strategic employment of the fleet, impose engaging tactically with the enemy's movable forces whenever possible, and, conformably to what we set forth in section 23, they impose engaging to a finish as far as the strategic situation permits.

A characteristic of naval battle is, that in it the constitution of a *reserve* cannot be admitted in the sense that it is understood on land. This difference is easily explained.

On land, when the battle begins, the strength of the enemy is not exactly known; it is not known where his principal mass gravitates; and in order to be in condition to face the situation at the moment it becomes clear, it is necessary to keep available a force to be hurled in an advantageous direction. Moreover, the idea of the gradual employment of the forces is logical, it being that of having troops that serve to support others already engaged, because the latter, besides the losses that they sustain, use up their energy; and hence it is in a high degree important to be able to dispose of fresh troops at the opportune moment, to be despatched in aid of the others.

It is, however, useful for our purpose to remember that even on land it would be dangerous to give too much importance to the criteria just mentioned. "Every reserve," writes Von der Goltz *(La Nazione armata),* "represents a dead force. Since the simultaneous employment of all the forces brings out the maximum efficiency, it would generally seem erroneous to constitute

reserves; but there is need of them in order to be able to meet unexpected incidents and sudden turns in the combat that are never lacking. If the situation is still more uncertain, if it is believed, for instance, that we may be exposed to many surprises, then strong reserves will be necessary. *The safer the situation,* and the better able we are to estimate concerning the enemy, the weaker the reserves may be. *We can even imagine a circumstance in which it would be logical to proscribe them; that is, when the enemy is completely displayed.* Now, such circumstances will certainly never be realized in practice, and, therefore, we ought never to fight without reserves. It is certain, however, that the opportune reserves are not always the heavy ones, but those that respond to the situation in which we find ourselves."

In the galley period, owing to the fact that a part of the vessels could sometimes be concealed, that the motive power was muscular, and that men fought hand to hand, there were presented conditions analogous to those of battle on land. But to-day the situation is far different; in naval battle we find ourselves in the ideal conditions in which, as Von der Goltz observes, reserves could be excluded even on land.

It might seem advisable to constitute a reserve formed of antiquated ships with scant protection, keeping them on the side of the alignment away from the enemy, and far removed from him so as to safeguard them. Their mission would be to attack injured ships of the enemy that might attempt to withdraw from the combat. But, ideas of this nature, if they were adopted, might bring about a repetition of the conduct of Albini's squadron on the unfortunate day of Lissa; let us remember that it was then said and repeated that wooden ships could not engage with hostile armored vessels. It would be better to leave the antiquated ships in port, or have them previously stricken from the list, rather than take them out before the enemy for the sole purpose of *safeguarding* them and confiding to them an illusory objective.

When it is deemed advisable to take into battle a few antiquated ships, because the offense of which they are capable is not to be despised, and because their speed is sufficient not to lessen the maneuvering qualities of the fleet, it is indispensable that they take a direct part in the battle, and only compatibly with this may they be safeguarded.

More generally, it is well to exclude the idea that while one part

of the ships is fighting, another part may remain in waiting; in such fashion we should offer to the enemy the means of beating our forces in detail; and a disastrous moral effect would be produced in the ships of the reserve. Indeed, let us figure to ourselves what was the state of mind of the personnel of the Russian cruisers at the battle of August 10, 1904, when, after the injuries sustained by the *Askold,* they were placed behind the armored ships.

The supreme importance of the battle demands that all the ships that have the gun for a principal weapon, shall fight from the start, assigning, however, to the various kinds of ships an adequate objective.

It is well known that Nelson, in the memorandum for Trafalgar, alluded to composing a division of the fastest sailers of the fleet, reserving it to himself to indicate, according to circumstances, to which of the two divisions it should join itself; with the intention, however, that the said division should participate in the battle without delay.

The vessels to be kept in waiting are limited to the destroyers and the torpedo-boats. It is not excluded that this light flotilla may render some service (section 69) in the phase of tactical evolutions; during the fleet action it will be kept in opportunely selected coast positions when the battle is developed in proximity to a friendly shore, otherwise they will be kept under the protection of the ships, or at a convenient distance, according to the employment that is had in view for them.

In determining the mission to be assigned to the various kinds of ships, *it must be borne in mind that the issue of the battle depends upon the combat between the armored fleets.* It would, therefore, be absurd initially to withdraw from such category any ship that has protection sufficient for taking part in the principal combat without excessive risk, or that, although having inferior protection (antiquated ships), has a powerful armament; in the latter case it will be placed in the outer line but close to the other ships so as to be able to fire in their intervals.

A few light ships will be necessary out of the line, on the side away from the enemy, in order to repeat signals; it may be advisable to have a repeating ship for every six ships of the line of battle. The other unarmored ships, formed into a fleet independent of the principal one, will have the task of engaging with similar ships of the enemy; so that it is to be presumed that, as at

Tsushima, there will take place a *secondary combat* simultaneously with the principal one.

75. *Contact out of Range.*—The party whose cruisers have established contact with the enemy's main body, according to what is said in the preceding chapter, prepares for battle on the basis of their information; or it alters the cruising formation as may be necessary, and steers so as to sight the enemy from an advantageous position.

If the conditions of visibility were limited, so that the distance of sighting the enemy were within the limit of offensive contact, the advantage in this way would be very great. Nevertheless, under good conditions of visibility the enemy will generally have time to assume an equivalent alignment. The evolutionary phase will then begin.

In Chapter III, of Part II, we endeavored to make it plain that it may be presumed that a phase of active maneuvering will take place out of range, with the object of securing an initial advantageous position. In contrast with the arguments therein adduced there could be cited a phrase of Nelson: "Between two fleets that desire to come to battle, the necessary maneuvers will be few; it will be desirable to make as few of them as possible."

Let us observe that Nelson was referring to the fleet of Villeneuve, which, it was to be presumed, would maintain a passive line of conduct, and that, naturally, he was not neglecting to prescribe the maneuver of approach so as to secure an advantageous position. Under analogous conditions, there is no doubt that the simpler and more rapid the maneuver of approach, the better it will be. Maneuvers out of range are a means of beginning the battle well, and they do not constitute a finality; hence they are absurd if they are not necessary. But if the enemy maneuvers so as to dispute with us the advantageous position which Nelson was not hindered from taking, it will be necessary for us to maneuver also, or resign ourselves to performing the part of Villeneuve.

76. *Offensive Contact.*—After the signal has been made at the beginning of offensive contact to indicate the guiding principle of the maneuver, other signals cannot be absolutely excluded, because it would be absurd for an admiral to renounce expressing his ideas when it is possible and necessary; hence it is natural that there should be battle signals, provided that they are simple and limited in number, and can easily be memorized.

If the commander-in-chief is on a ship in line with the others, he is exposed to great dangers, it being presumable that the said ship will be the principal object for the concentration of fire. But it would certainly not be logical to revert, for that reason, to the solution adopted by the French after De Grasse was made prisoner at the battle of the Saintes, that is, to the system of placing the commander-in-chief on a light ship out of the line—a system they were obliged to abandon.

Tactical maneuvers must, as we know, be based essentially upon the following of movements; so, then, if the commander-in-chief were out of the line, it would be necessary to depend exclusively upon his signals.

To the end that the commander-in-chief may have a well-grounded hope of exercising his directive functions, it is necessary for him to have a means analogous to that which is available on land by means of the reserve; that is, it is necessary for him to have a division under his immediate orders.

Now, we bear in mind that, in tactical maneuvering, the regulating ships of all the divisions are those at the extremities; in order to render minimum the necessity for signals, it is then necessary that there be an admiral at the extremities of the formation of each division. In order that the inconveniences may be minimum in case the commander-in-chief is disabled, it is necessary in such circumstances for his division to continue to be the regulator; that is to say, it is well for the second admiral of the division under the direct orders of the commander-in-chief to be the second in command of the fleet.

It might be held desirable, still satisfying the above-mentioned condition, that, in a line formed, for example, of 12 ships in two divisions of six ships each, the second in command be at an extremity and the commander-in-chief in the center; but we believe he would repent having yielded the position of honor, as Farragut repented it at Mobile.

Having to fight a fleet more powerful than our own, it might seem desirable to seek battle under the forts, in order to find in their support a compensation for our own inferiority. But this would dangerously hamper the strategic employment of the fleet, as well as its tactical employment; and these hindrances might carry with them such detriment as to overbalance the gain in offensive power constituted by the action of the forts.

The issue of offensive contact will not depend upon maneuvering and ability in firing alone, but moral factors will have great part in it.

We can never be sufficiently imbued with the fact—examples of which are not lacking in history—that often one is beaten solely because he is persuaded that he is beaten. Daveluy justly affirms that he who engages in battle with the firm determination of not yielding, is already half a conqueror. On the contrary, he who goes into battle believing that he is accomplishing a useless sacrifice, will hardly succeed in finding energy to give rational direction to the conduct of the forces. Defeat in that case will not be glorious, since, although the situation may be most desperate, there always exists a rational plan to be adopted.

Battle serves to create between combatants differences in order, in material and in morale; in the pursuit we may gather the fruits of such differences and accentuate them in much greater proportion.

The separation of the forces for the pursuit depends upon the separation of the enemy's forces. When, during the night that follows the battle, contact with the enemy is lost, owing to the necessity of leaving a clear field for the action of the torpedo-boats, it will be endeavored, on the following morning, to re-establish the contact, profiting by our conditions of superiority so far as to abandon, at least in part, those precautions that would be indispensable against an enemy in full efficiency. Even the battleships may then be extended in chain for the search.

77. *Tactical Exercises.*—The tactical skilfulness of a fleet can be obtained only through *frequent exercises with parties opposing each other.* As a preparation for these exercises at sea, the tactical game may be profitable; nevertheless, the profitable return of this game is somewhat limited for various reasons, among which are the impossibility of reproducing in them the steering by sight vane, and, more generally, the impossibility of regulating oneself by the enemy in a continuous manner.

To the end that the tactical exercises may be conclusive, it is indispensable that those who are called upon to execute them should possess a sufficient substratum of theoretical knowledge.

THE END.